JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CV. FEBRUARY, 1878. No. 2.

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NEW PRINCIPLES OF HYDRAULICS.[1]

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I.—FUNDAMENTAL PRINCIPLES.

PROPOSITION I.—In any vessel or tube from which a liquid flows out, the flowing liquid (which we will call flowing vein) consists of a certain number of elementary liquid fillets, having origin upon the level surface of the liquid in the vessel or tube.

We indicate by A, a particle or molecule of a liquid which passes through a vessel or tube; and by B, the position of this molecule at a given instant, in a section Ω, of said liquid. In the following instant, for "continuity," another molecule, A', must occupy the position B of the molecule A; and for the same reason, at the same time, another molecule, A'', must occupy the position B' of the molecule A', etc. Continuing to reason in this manner, it will readily be seen that we will arrive at the level surface of liquid in

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the vessel; and, therefore, we can conclude that the molecule A belongs to an elementary liquid fillet, A, A', A'', A''', ..., disposed on a certain line, B, B', B'', B''', ..., having origin on the said level surface. The same as for the molecule A, will be true for each molecule which passes through the section Ω; therefore, the proposed theorem is demonstrated.

Corollary.—The theory of the linear motion of fluids is inadmissible, because if we indicate, by $\delta\ \omega$, the section of one elementary liquid fillet, and by n, the number of fillets which constitute a given vein, through whatever vessel or pipe this vein passes, and whatever cross-section of this vessel or pipe we consider, the real section of the flowing liquid will be always

$$n\ \delta\ \omega = \omega;$$

while this theory admits that, in a tube of variable section, the section of the flowing liquid is also variable.

(In future, ω will represent the real section of any flowing vein, and $\delta\ \omega$ that of a single fillet.)

PROPOSITION II.—During the motion of a vein through a pipe of uniform section equal to ω, the principle of equal pressure, or Pascal's principle, cannot be verified; that is to say, if the vein is compressed in direction of its directrix, the compressing force does not produce bursting pressure in the pipe.

In fact, when a liquid at rest, contained in a vessel, is compressed, to transmit the compressing force upon the internal walls of this vessel, any of its molecules must push, "eccentrically," the others in direction of its real or virtual movement; that is to say, must act as a wedge upon them, and this fact cannot be verified in a vein which moves through a pipe of uniform section equal to ω, when it is compressed in direction of its directrix, being incompatible (Proposition I) with the disposition of its molecules.

Scholium.—Observing that the elementary liquid fillets which constitute the vein must be disposed as indicated in the annexed Fig. 1, that is to say, in such manner that one molecule of a fillet touches two molecules of each of the adjacent fillets (this being the only disposition compatible with the unalterability of density of the liquid), we see that, compressing the vein in direction perpendicular to its directrix (or in section), the

Fig. 1.

compressing force will be transmitted in direction of said directrix, at both parts of the compressed section of the vein.

Corollary I.—When a liquid passes from rest to motion, or *vice versa*, the disposition of its molecules changes. This fact could be of great interest in physics.

Corollary II.—During the motion of a vein through a pipe of uniform section equal to ω, the pressure experienced by this pipe arises only from the weight of the vein and from the centrifugal force of its molecules.

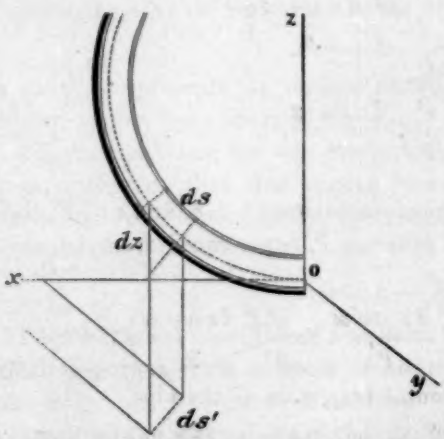
Important Remark.—All the molecules in every liquid fillet of a given vein, move with equal velocity; therefore, at each instant, the motive and resistant forces which act upon each one of them must be in equilibrium; and the same must be true of the motive and resistant forces which act upon every section of the vein.

II.—Equations concerning the Motion of Fluids.

Proposition I.—To find the pressure which is experienced by a pipe of uniform section, through which passes a flowing vein with uniform velocity, the section of the pipe being equal to ω.

Let $s = F(x, y, z)$, be the equation of the directrix of the pipe, Fig. 2, the lowest point of which is origin of the co-ordinates, and the axis z, vertical. Moreover, let u be the constant velocity of the vein; z, the vertical height of the pipe, and we suppose the whole weight of the vein uniformly concentrated on its directrix s, which we imagine divided into infinitesimal parts ds, each one of a weight dq. Let z and $z + dz$ be the vertical ordinates of the ends of an infinitesimal arch ds; and we decompose the weight dq of this arch into two forces, one acting in direction of the tangent; the other in direction

Fig. 2.



of the normal considered in the vertical plane passing through ds; the latter will be

$$dN = \frac{ds'}{ds} dq,$$

ds' being the horizontal projection of ds. And observing that (when the specific weight of the liquid is unity) $dq = \omega\, ds$; substituting, we find

$$dN = \omega\, ds'.$$

Moreover, let ρ be the radius of curvature of the arch ds; and α the angle which it forms with dN; the centrifugal force of ds will be

$$\frac{ds \,.\, \omega}{g} \cdot \frac{u^2}{\rho};$$

which, decomposed into two, one acting in the direction of dN (conspirant or non-conspirant with this force), and the other acting in a perpendicular direction, will give for the first,

$$\pm \frac{\omega\, u^2}{g} \cdot \frac{ds \cos \alpha}{\rho};$$

and for the second,

$$\frac{\omega\, u^2}{g} \cdot \frac{ds \sin \alpha}{\rho}.$$

Therefore, the pressures, experienced by the pipe in the considered section, are

$$\omega\left(ds' \pm \frac{u^2}{g} \frac{ds \cos \alpha}{\rho}\right),$$

acting in a vertical plane, and

$$\omega \frac{u^2}{g} \cdot \frac{ds \sin \alpha}{\rho},$$

acting in a horizontal plane,

Integrating these two expressions between $z = o$, and $z = Z$, their sum will represent the total pressure P, experienced from the whole pipe, which pressure will be

$$p = \omega \left(s' \pm \frac{u^2}{g} \int \frac{ds \cos \alpha}{\rho} + \frac{u^2}{g} \int \frac{ds \sin \alpha}{\rho}\right);$$

s' represents the whole horizontal projection of the pipe.

Proposition II.—To find the resistance to the flow of the preceding vein.

Indicating by f the coefficient of friction of the vein with the walls of the pipe, the frictional resistance will be

$$pf = \omega f \left(s' \pm \frac{u^2}{g} \int \frac{ds \cos \alpha}{\rho} + \frac{u^2}{g} \int \frac{ds \sin \alpha}{\rho} \right).$$

Indicating now, by θ, the force of adhesion of the liquid with the walls of the pipe (this force is independent of the pressure p), and by i, the ratio of the perimeter of the section of the pipe to the area of the same section, the total adhesion of the vein upon these walls will be $\omega i s \theta$; therefore, the total resistance to the flow of the vein will be

$$R = \omega \left[i s \theta + f \left(s' \pm \frac{u^2}{g} \int \frac{ds \cos \alpha}{\rho} + \frac{u^2}{g} \int \frac{ds \sin \alpha}{\rho} \right) \right]. \quad (a)$$

PROPOSITION III.—To find the motive force which animates a section of a flowing vein, outside the orifice from which it disgorges.

Indicating, by h_1, h_2, h_3, ... h_n, the vertical heights of the n fillets of the vein which rest upon the section which we consider, the motive force of this section will be

$$P = \delta \omega (h_1 + h_2 + h_3 + \ldots + h_n);$$

or, multiplying and dividing for n,

$$P = \omega \frac{h_1 + h_2 + h_3 + \ldots + h_n}{n} = \omega h.$$

Considering also the resistance to the flow of the vein, will be

$$P = \omega h - R;$$

in which h represents the vertical distance of the centre of the considered section from the level surface.

Scholium.—When the vein moves with uniform velocity, we know, from mechanics, that this motive force must be equilibrated by a resistant force; consequently, the considered section experiences a pressure equal to the motive force

$$P = \omega h - R.$$

PROPOSITION IV.—To find the actual velocity of a flowing vein, which disgorges from a vessel of constant level surface and rises vertically.

Let h' be the vertical height of the liquid jet outside the orifice of the vessel (which jet we suppose of constant section ω). When the weight of this jet becomes equal to the motive force P, which

animates its lowest section, the velocity of the vein becomes uniform, and then will be

$$P = \omega h - R = \omega h',$$

from which

$$h' = h - \frac{R}{\omega}.$$

Otherwise, by law of the vertical rising of the bodies, the liquid, to rise at the height h', must have the initial velocity

$$u = \sqrt{2 g h'};$$

or

$$u = \sqrt{2 g \left(h - \frac{R}{\omega}\right)}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

When $R = 0$, we have

$$u = \sqrt{2 g h};$$

and in this consists the celebrated principle of Evangelista Torricelli.

Scholium.—Experience teaches us that the velocity of a flowing vein, which disgorges from the orifice of a vessel of constant level-surface, is uniform, whichever direction the liquid jet takes outside this vessel. Consequently (Proposition III, Chap. II), in any jet, the liquid section which occupies the area of the orifice of the vessel must be equilibrated. Now when a liquid jet is ascending, its own weight can equilibrate the motive force of this section; but if the jet is descending or horizontal, what resistant force equilibrates this motive force? Therefore, independently of gravity, we are compelled to admit an invisible resistance, which must act at least upon any descending or horizontal jet when it moves with uniform velocity. This new resistance takes place in the following manner:

The molecules of the flowing liquid, on leaving the orifice, independently of the general acceleration of the vein, receive a new acceleration which arises from their passage from the vessel to the air, where the resistance to the flow diminishes. Consequently, they attempt to separate from the vein, producing a vacuum. Then the atmospheric pressure becomes active, compresses the jet upon a more or less extended length (from which arises the *vena contracta*); and, as demonstrated (Prop'n II, Chap. I, Sch.), the compressing force P' of the jet is transmitted on one side, against the motive force P of the vein, and on the other, against the jet, dispersing it in the air. But the compressing atmospheric force P' increases with the accel-

eration of the vein; therefore, the movement becomes uniform only when

$$P' = P = h\omega - R.$$

Corollary.—The equations found in the preceding Proposition IV, as well as Torricelli's principle, are applicable to any jet.

(We observe that the distinguished disciple of Galileo had no right to generalize his principle.)

PROPOSITION V.—To find the actual velocity of a vein, which, from a vessel of constant level-surface, passes through a pipe of uniform section equal to ω.

In the equation (b), substituting, instead of R, its value (a); (neglecting the frictional resistance of the vein in the vessel as very small), we will have

$$u = \sqrt{2g\left[h - is\theta - f\left(s' \pm \frac{u^2}{g}\int\frac{ds\cos\alpha}{\rho} + \frac{u^2}{g}\int\frac{ds\sin\alpha}{\rho}\right)\right]}.$$

Squaring and resolving with reference to u, we will find

$$u = \sqrt{2g\,\frac{h - is\theta - fs'}{1 + 2f\left(\int\frac{ds\sin\alpha}{\rho} \pm \int\frac{ds\cos\alpha}{\rho}\right)}}.$$

If the vein moves on a vertical plane, $\alpha = o$, and

$$u = \sqrt{2g\,\frac{h - is\theta - fs'}{1 \pm 2f\int\frac{ds}{\rho}}};$$

and, if $\alpha = 90°$,

$$u = \sqrt{2g\,\frac{h - is\theta - fs'}{1 + 2f\int\frac{ds}{\rho}}}.$$

When a pipe is rectilinear and inclined, will be

$$u = \sqrt{2g(h - is\theta - fs')}, \quad . \quad . \quad . \quad . \quad . \quad (c)$$

and, if vertical,

$$u = \sqrt{2g(h - is\theta)}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (d)$$

In practice, the water-conduits are formed of cylindrical pipes and circular bends, the inclination α of which is known. Therefore, if we represent, by c, the length of the directrix of a bend; by r its radius; the velocity u can be expressed in this manner:

$$u = \sqrt{2g\,\frac{h - is\theta - fs'}{1 + 2f\left(\Sigma\frac{c\sin\alpha}{r} \pm \Sigma\frac{c\cos\alpha}{r}\right)}};$$

an expression which can always be calculated with sufficient exactness, when the coefficients θ and f are known.

For determining the coefficient θ, it is sufficient to test the velocity u of a vein, through a cylindrical and vertical pipe of determined length, and substitute its value in the formula

$$\theta = \frac{2gh - u^2}{2gis},$$

deduced from the equation (*d*).

When the coefficient θ is known, for determining the other, f, it is sufficient to test the velocity u of a vein through a cylindrical and inclined pipe of a determined length and inclination, and substitute its value in the formula

$$f = \frac{2g(h - is\theta) - u^2}{2gs'},$$

deduced from the equation (*c*).

It is necessary to observe that the coefficients θ and f will be different for pipes of different materials.

III.—Theory of Water-Wheels.

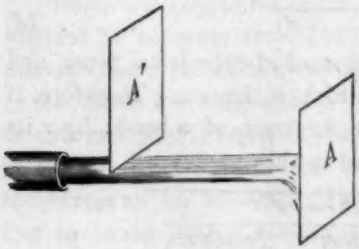
We have seen in the preceding chapter (Proposition III, Sch.), that the pressure experienced by a given section of a flowing vein, outside the orifice of the vessel from which it disgorges, is

$$P = \omega h - R = \omega \frac{u^2}{2g},$$

in which u represents the actual velocity of the vein.

Now if at the place of the given liquid section we imagine a plate which moves with the same velocity u of said section, this plate will experience also the same pressure P; therefore, if a plate is pushed by a flowing vein with relative velocity equal to zero, it will experience a pressure equal to the weight of a liquid column of the same density of the vein, having its base equal to the section ω of the vein, and its height equal that due to the velocity of said vein.

Fig. 3.



We imagine, now, a system of two thin plates A, A', thus (Fig. 3): that one, *i. e.*, A, enters perpendicularly in a flowing given vein, and moves, at the same time, par-

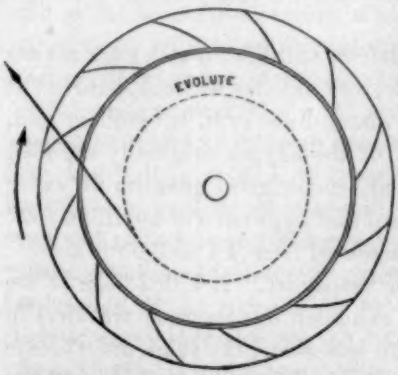
allel to itself, with the same velocity u of the vein. When it arrives at a certain point, it begins to come out from said vein, moving it always parallel to itself with velocity u. Then the other plate, A', enters in the same manner as the first, repeats the same movements, and, before coming out, re-enters the plate A, and so continually.

If we suppose the plates A, A', so thin that we may neglect the resistance which they encounter entering perpendicularly in the vein, it is clear that (without calculating any other passive resistance) the system above mentioned will give a useful effect,

$$L_u = \omega \frac{u^3}{2g},$$

and, from mechanics, we know that this is the maximum effect which a flowing vein can produce; that is, the absolute maximum useful effect of the system. Therefore, the question of the water-wheels is now merely a question of kinematics; because, if we find a wheel such that its buckets satisfy the same conditions as the system of plates, A, A', we shall always obtain the absolute maximum useful effect. This question we have fully resolved with our patented water-wheel, Fig. 4 (pat. 1877, U. S.), having its buckets of very thin plate, and curved as an arch of the involute of a circle concentrical to the axis of the said wheel. The propelling water acts upon them from inside to outside the wheel, in direction of the tangents to the evolute, and it is very easy to see the perfect identity of conditions between this wheel and the system of plates A, A', above described.

Fig. 4.



If the propelling water encounters the buckets with relative velocity greater than zero, the pressure upon them increases, but the velocity of the wheel diminishes. In this case the useful effect would be equal to the absolute maximum useful effect, but cannot be greater.

Our water-wheel can be disposed horizontally, as well as vertically. It is the practical expression of our theory, and the limit of perfection of any water-wheel.

ON THE RELATION OF MOISTURE IN AIR TO HEALTH AND COMFORT.[1]

By Robt. Briggs, C. E., Cor. Mem. Am. Inst. of Architects, etc.

[Continued from Vol. lxxv, page 20.]

§ It is with some reluctance that I refer to the "Theory of Ventilation." The past eighty years have witnessed the growth of chemical science, which, after passing through numerous stages of development, as witnessed by the different nomenclatures, has finally reached the point, that only the chemists of continual study can comprehend it, and at which point he who knows most about it is the least satisfied with its present condition.

But thirty or forty years since, chemistry was supposed to have unlocked the mysteries of matter, and by the extension of the simple rules applicable to the gaseous and metallic elements, it was thought that the cause of disease or health was to be discovered. Careful observers then examined, from the chemical standpoint, the constitution of the air, both fresh and vitiated; and writers, with good logical conclusions, enunciated a *Theory*, by which is was made evident that chemistry had uncovered the root of disease, and carbonic acid gas was the fatal cause.

The real facts are these: An adult in still life inhales each minute about 480 cubic inches of fresh air, and exhales 488 cubic inches of vitiated air, of which vitiated air about 4 per cent. is carbonic acid, and from which about 19 per cent. of the oxygen originally supplied by the fresh air has been abstracted; the original quantity of vapor in the fresh air at mean temperature and hygrometric condition (62° and 65 per cent.) will have been increased from 1·1 to 3·08 grains.

Carbonic acid gas was made the scapegoat. It killed dogs at the Grotto del Cane, as was happily exhibited to numerous travelers in Italy at that time—and both before and since, the same unfortunate dog serving to be killed, to the satisfaction of admirers, that had been resuscitated the day before, after the visitors' backs were turned. It was heavier than air, and in some conditions of temperature would not so readily diffuse, but form a layer of distinct gas, like water beneath oil. Altogether it answered the conditions of hypotheses,

[1] Paper read before the Am. Institute of Architects, at Boston, Oct. 18th, 1877.

and it was decided to be vile, deleterious, poisonous. To be sure, we devoured it in bread and drank it in beer, or aerated waters, but then the poison was to the lungs, not to the stomach! This theory found promulgators in the lecture rooms, and advocates in the household thirty years ago, and has become to-day the *traditional* belief of the middle aged and elderly. If a room is hot or close from excess of temperature, or from a crowd of occupants, carbonic acid gas is the difficulty; if malaria is developed in a jail or hospital, or typhus or scarlet fever exist in the dwelling, carbonic acid gas in excess is the poison. "The gas is heavier than air, and must necessarily sink to the floor, where all the air of vitiation will be found." These notions continue to have advocates and supporters to the present time, and the popular lecturer or writer gives a half assent to them, to secure the favorable opinion of audiences or readers. But step by step, during the past thirty years, it has come to be perceived that the causes of disease are not to be found with inorganic matter, and carbonic acid has been removed from its elevated place in ventilation, with the fullest admissions, that in the quantities ever present in the living rooms, except by accident, it is quite harmless; and finally, its presence has been accepted as merely a measure of other more dangerous vitiations, in that as it is a definite product of respiration, and as the proportion present in any room, at a given moment, can be ascertained with tolerable exactness, an indication can be derived thereby of the extent of organic vitiation with some degree of certainty.

The unquestioned theory of malaria, the meaning of which word can be extended to embrace diseases arising from deficient or defective ventilation, to-day, is organic vitiation, and the probability of this theory holding its place in future, is, I think, a very fair one. The exhaled and exuded vapor from the human body is known to be laden with organic matter; much of this organic matter is within the range of the microscope, by means of which the local derivation of many particles can be determined; but some of it is in the form of effluvia and odors, which pass the limits of visual observation in the smallness of the atoms, notwithstanding such effluvia or odors are decidedly perceptible to the sense of smell. With a dry external atmosphere and a reasonably free ventilation, the exuded vapor and the organic matter pass away, or are diffused as rapidly as supplied. *It should be remarked that the organic matter appears mainly to be in connection with the vapor in the air, and not to exist*

as a separate gas, diffused in the dry air when the vapor is removed by natural causes. With an imperfect or insufficient ventilation, the upper parts of rooms become filled with air, which will be found to contain a much larger proportion of moisture than the lower portions, and will be shortly found to be exceedingly offensive from the rapid decomposition which the exuded organic matter undergoes in a moist air. This will happen more frequently when the internal and external temperatures are about the same, and when it is so cold, raw, or windy, as to require closed doors and windows, with only a small addition of heat, and when with these conditions the natural dew point is high. These circumstances are in concurrence frequently in England, where probably 120 days out of 365 call for but small addition of heat in rooms, while they rarely exist with us; the climate of our northern United State not giving 30 days in any year of similar kind. The objection of *effluvia*, which forms the distinctive one in audience rooms in England, and is so noticeable to the American visitor of such rooms, is replaced in our halls by a simple sense of oppression—a mere feeling of discomfort—which, on the other hand, is particularly noticeable to the English visitor of our halls, who is apt to associate it with a supposed excess of heat.

But this organic matter of exhalation is still one step removed from malaria, it is only the ground of malaria—the soil on which a malarial growth will propagate; its *decomposition* is held to supply the means of fecundity to the germs of disease. In the warm air confined in the upper parts of rooms, with excess of moisture, it may undergo a rapid and somewhat fetid decomposition; under such circumstances it is found to become offensive in six to ten minutes. With a smaller proportion of moisture, or when it is rapidly absorbed with the moisture by diffusion into air of American dryness, it does not decompose so rapidly, but is likely to be absorbed by any hygroscopic substance the air containing it may come in contact with. The walls of rooms, especially the porous plastering, stone or bricks, and possibly the papered and painted walls, will take up the excess of moisture with its organisms, and give up at another time, wholly or in part, the moisture without them. There is a characteristic smell of walls of kitchens, cabinets, hospitals, jails, court rooms, and similar permanently occupied places, which can be developed in intensity by simply holding the half closed warm hand against the face of the wall, and testing the result by the sense of smell of the hand. In

such instances of retention of the results of imperfect ventilation, the eventual propagation of disease is a certain one.

To the vegetable and lower animal growth, the presence of moisture in the air seems a positive necessity; where it is absent they perish, or at least no longer grow or propagate. The drinking animal apparently suffers the least of injury, and but little discomfort in the dryness of the air of whatever temperature. The immunity from disease to the human race which accompanies the dryer regions of the earth, has been frequently remarked, and the fact meets general assent. The discomfort of the colder countries, even to the limits of the arctic regions, is one of cold, not of absence of moisture. The assertion of relative insensibility to cold air devoid of moisture, is the common report of all travelers in such regions; while the dreaded malarial diseases of more genial lands do not exist in them at all. In the temperate zone, in countries or localities which possess the dryest of atmospheres, with the least variation of hygrometric condition, mankind is most free from disease of all descriptions. The elevated dry and barren lands of our midland country, from Minnesota southwardly, are the healthiest regions of the United States; and where, together with the *dry* atmosphere, some uniformity of temperature exists, as in Mexico—where the height above the level of the sea reduces the sensible heat of the air, which is usually found in that latitude, to a comfortable one—there we have the acknowledged climate of utmost healthfulness. Going into more torrid lands, the dryness of the air alleviates the heat of the deserts of Arabia, and of Africa, of Peru and Bolivia, where the temperature rises at times to 110° or even 120° in the shade. I have the assertion of a friend that on a hot day, with the thermometer nearly 100°, he has known the wind on the Arabian desert to be searchingly cold, when everything was shriveling up for want of moisture. My attention was called by Dr. J. S. Billings to the following extract of his report on the Hygiene of the U. S. Army in 1875:—"Description of military posts, Fort Yuma, California. Reports of Asst. Surgeons Lauderdale and Ross, U. S. A. After describing the locality of the post, near the junction of the Giler and Colorado Rivers, they say: * * * 'The heat increases rapidly from the latter part of May, and in June, July, August and September may be said to be intense * * During the months of April, May and June no rain falls; then, with the thermometer at 105°, the perspiration is scarcely seen upon the skin,

and it becomes dry and hard, and the hair crispy, and furniture falls to pieces, * * ink dries so rapidly upon the pen that it requires washing off every few minutes. * * A No. 2 Faber's pencil leaves no more trace on paper than a piece of anthracite, and it is necessary to keep one immersed in water while using one that has been standing in water some time. Newspapers require to be handled with care, if rudely handled they break. Twelve pound boxes of soap, when reweighed, gave but ten pounds. Hams had lost 12 per cent. and rice 2 per cent. of original weight. Eggs that had been on hand for a few weeks lose their watery contents by evaporation, the remainder is tough and hard; this has probably led to the story that our hens lay hard boiled eggs.

"'The mercury gained its highest point last summer on the 2d day of July, when for two hours it stood at 113° in the shade. All metallic bodies were hot to the touch, my watch felt like a hot boiled egg in my pocket * * *

"'This post, although not the most southerly, is the hottest military post in the United States; the highest temperature recorded on our books since 1850, when the post was established, is 119°, observed at 2.25 P. M., June 16th, 1859. A temperature of 100° may exist at Fort Yuma for weeks in succession and there will be no additional cases of sickness in consequence * * * We have none of the malarial diseases * * No ice is formed at any time; 29° has been indicated by a registering thermometer in January, 1872. The mean temperature, day and night, of January, however, is 57°; that of July is 95°. The average rainfall during four years was a little over 2 inches each year.'"

Any who wish to corroborate or question these views as to the healthiness or unhealthiness of dry air, hot or cold, can examine authorities, or investigate or observe for themselves; the conclusions they will reach can be confidently anticipated. But the proof or argument cannot be further extended in this paper, and it must be claimed that there exist good grounds to believe that dry air, *per se*, of whatever temperature it may be found on the surface of the earth, is not unhealthy; that, as regards disease, such air possesses both preventive and curative qualities of great value; and that, on the other hand, moist air, such as promotes vegetable growth, is not desirable for breathing on sanitary grounds. Asserting these views, the question narrows down to: given a habitat or place of residence, where some

degree of moisture and vegetation does thrive for a portion of the year, at least—what effect on the system do the variations of moisture produce, from season to season, from day to day, and during such of the seasons as the comfort of inhabitants may call for artificial warmth, from one place to another on the same day?

§ Clothing, houses and fires are the means by which mankind is enabled to inhabit the face of the earth. It is an artificial existence for an animal whose natural life would otherwise be limited to a small belt of the torrid zone, where the temperature never falls below about 80°, nor rises above 100°. As residents of the northern United States, we cannot expect to avoid, and do not expect to ameliorate, the vicissitudes of climate *out of doors*. Hot or cold, rainy or dry, with air relatively humid or otherwise, life in all countries means endurance under artificial guards or protections from natural inclemencies. We clothe ourselves by the umbrella on the one hand, or the great coat on the other; open or close our doors; induce cool breezes, or gather around fires, in search of the *comfortable uniform* loss of heat by the system. The efforts to accomplish this end, by means of change of temperature or relative moisture of the air, are of necessity confined to the cold, or at least cool, season, with infrequent attempts to obtain an artificial degree of cold in extreme hot weather. In moderate weather, the vicissitudes of temperature, and of humid condition of the air, are endured with the expression of discomfort and the tacit admission, on all hands, that our great day-by-day variations of the mild season are harmful to the feeble or sickly. But these daily changes of temperature and of hygrometric condition are of small account with those which in the Northern states accompany the season of cold. The change of climate from that which accompanies, during any of the winter months, our warm south winds, to that which accompanies a great northwestern wind wave which may follow the southerly breeze within twelve hours; a change from 50° to 60°, with 80 per cent. saturation, to even below zero, with an unascertainable dew point: such a change is trying to the extreme. The prevalent disease of the land is consumption of the lungs, and these changes are disastrous to those who are suffering from this complaint; and, to the healthy, these changes are held to be fraught with danger.

§ A very simple and commonplace observation will make the general condition of air in rooms in winter, as regards humidity, the subject

of positive demonstration. During the season of winter in our climate, after a continued spell of cold weather, the exhibition of condensed moisture or of frost on the window panes is very unfrequent. The usual provision of glass in windows throughout the northern United States, is in single thickness, not double plates; the latter arrangement being decidedly exceptional as a means of preventing transfer and loss of heat at the windows. The temperature of a pane of glass which is interposed between two temperatures of still air, that is of air devoid of currents, except those generated by the differences of temperatures of the air on either side, and the glass, is obviously that of a mean between the said two temperatures of air. With so good a conductor as glass, and with plates as thin as ordinary window glass, the conductivity of the glass may be assumed to be perfect, and both sides of a pane can be deemed to have the same mean temperature. But the temperature of the air on each side of a pane differs from either that of the external air on the one side, or of the room on the other. On the outside, the layer of cold air in contact with the pane ascends slowly as it is heated, and the vacuity which is formed at the bottom of a pane is supplied by fresh cold air, so that the layer at this point approximates to the temperature of the outer air closely. On the inside, the layer of warm air in contact with the pane descends as it is cooled, having, perhaps, an approximation to the inside temperature at the top of the pane, but by the time the layer has flown downwards to the bottom of the pane, its temperature will have become materially lower than that of air of the room generally. So that while the law of mean temperature of the pane at the bottom of the pane is yet good, the real temperature may be much lower than a simple mean between thermometers hung in the room and out of doors. Beside the supposition of still air, much allowance must be made for the effect of winter winds in accelerating the flow of cold air on the outside of the pane until the outer layer is very nearly of uniform coldness, which favors the greater abstraction of heat from the internal descending current, and cools down the lower part of the pane still further. Curtains, shades or internal blinds, while they aid in protecting the room from loss of heat, also protect the glass from acquiring the temperature due to the heat of the room. Until with the supposed case of external air at 10° above zero, and a moderate wind out of doors, and of a room warmed to 75° inside, the

temperature of the panes near the bottom, or even well up their height, will be much below 42½° as the mean; and 27° to 28° may fairly be taken as giving the real temperature near the bottom. This pane of glass becomes then a dew point thermometer at all times in the winter, ready for indicating the humidity in the air. Except, however, a crowd of people, or some artificial "hydration" carried possibly to momentary excess under the stimulus of the last theorizer, or a very new house, or a damp cellar in an old one, we but rarely see any indication of presence of moisture in our dwellings in cold weather. This simple test will show that our dwellings, although the water troughs of the hot air furnaces do supply limited quantities of vapor with admitted comfort, do not, as a rule, have over 30 to 40 per cent. of humidity in the air within them.

The entire range of our Atlantic coast is only removed from a region of perpetual spring from 200 to 500 miles; and a southeast wind, from December to April, may bring a vapor laden air, which, in a few hours, will have changed our frigid winter to a genial spring. The succeeding wave of northwest winds—a great current which the Signal Service has traced up to the Arctic regions—may, with great violence, restore the winter with all its rigor, within another few hours. Under this change, heavily frosted windows become the rule, and they indicate a dew point above the temperature of the panes of glass, at once. So dry and arid are these winds, however, that with the continuance of a northwest wind for a single day, all traces of window frosting will have disappeared.

This test of the dew point by the window, is very accurate. As an instance, I will quote that on one day in this present month, in Philadelphia, with the thermometer in-doors at 64°, without fire, a fall of temperature to 54° outside, produced immediate condensation on windows, showing 75° to 80° of humidity. Now if a difference of only 10° produces this indication for *humid* air, the want of such an indication with difference of up to 65°, must manifestly be a very dry air. By actual trial in well warmed and ventilated rooms, the writer has found the dew point far below the freezing point of water, in rooms where the sensation of dryness, which is held to accompany the heat of the furnace when not supplied with water for evaporation, certainly did not exist.

It is proper when alluding to the dampness of houses, to advert to one of the most striking differences between England and western

Europe, and the northern United States, in the necessities which climate imposes in the relation of humidity in air to the health, in this particular regard. We find all foreign authors speaking in unequivocal language of the great danger of inhabiting a newly built and consequently imperfectly dried house. One English writer, whose name I cannot recall, but I remember to have been of much eminence, asserted that no house ought to be occupied until a year after completion. Many writers on ventilation join in estimating by figures the quantity of moisture in the new walls, and *demonstrate* the dangers of a residence, where the excess of moisture in the air, the want of permeability of the walls, and the increase of conductivity of heat through the damp walls, will have produced such a tomb-like house. While in America we are fully alive to the danger in the house, from air overladen with moisture, as from a damp cellar, or location in a damp place or vicinity, and appreciate that rheumatism and consumption, with scarlet fever for the children in winter, when the house is thoroughly warmed, and typhus for adults in mild weather, are the possible, if not probable, penalties for living in such a house; yet the new house, from its inherent dampness, only is considered at least as but objectionable in a small degree. Except that dampness exists from other sources than that which comes from the walls, our new houses are quite as healthy during the first year, or the first season's occupation, as afterwards. No preliminary drying out is needed as a rule. Our summers or winters are dry enough to take up all the moisture which walls may give, without overlading the air with humidity; although it is noticeable, that new houses require more fuel to warm them the first winter than afterwards, as the supply of heat must be sufficient to evaporate an excess of moisture, and the conductivity of the walls is somewhat greater before they are thoroughly dried out. Few dwellings are completed for occupancy at the end of winter or of summer—residence generally begins with the beginning of summer or of winter, and the seasons when the dampness of walls would be dangerous from the existence of a humid air are not those when new houses are generally first occupied.

§ Although not directly related to the subject, I will mention here one curious demonstration of the effect of atmospheric humidity and impurity which is peculiar and common in England. All American readers, or observers, become aware of the great importance attached by the English public, as a people, as writers, and as a government, to the

relative purity of illuminating gas, but it is not generally known, or even asserted, that the cause in England which makes the impurities of gas obvious, and renders them seriously objectionable, is to be found in the air of the room, and not alone or even mainly in the gas itself. The sense of oppression from the burning of gas in dwellings in England, is one that can be appreciated only by being felt; any description fails to convey to the mind of the untraveled American, the burden on the breathing functions which results from gas burning in a humid and impure air. It is enough to say that throughout England, gas lighting is regarded as only suitable for shops, workrooms, warehouses, public rooms and such other places, within or without of doors, as demand light for passengers, rather than for occupants. When halls are lighted by gas, the chandeliers (gasoliers is the English word) and bracket lights are not considered to be well arranged unless "ventilated;" in other words, provided with especial means—air passages or outlets—for removal of the gases of combustion, with the accompaniment of a volume of heated air. The dwellings—dining and drawing rooms, passages, and chambers—of the more wealthy, are lighted nearly universally by candles of wax, sperm, or some prepared fatty substance, either animal, vegetable or mineral, with the occasional or frequent use of the carcel-lamp as a table light. From any English gas light there arises a current of impurities which in a brief space of time discolors, and coats with black, the interior of the ventilating tubes, or, in absence of such protectors, the canopies of glass or metal which are usually supplied for unventilated burners; or when this last protection is wanting, the ceiling, even when several feet above the burner, is quickly marked by a halo of greasy soot, which adheres to it where the ascending current impinges.

The heat emanating from a gas burner, as compared to that from a number of candles giving the same amount of light, is very nearly the same, about seven per cent. more heat being given out by the candles; but the 14 to 16 candles, which represent the single gas burner, will have been dispersed about a room, or even when grouped in threes or sevens, as usual in sconces, candelabra or chandeliers, will be spread widely asunder, so that the current proceeding upwards from each separate candle will have become diffused before reaching the ceiling; and, if the candles give out the same impurities (which they do not) as the gas burners, the obvious impurities which make a mark will not be precipitated to show themselves as spots. Besides

this, a room lighted by candles will be considered brilliantly illuminated by three or four candles, where one gas burner would have been used; so that one-fourth the quantity of light will be made to suffice with candle illumination, to what is requisite for gas lighting. The numerous candles come in proximity to the objects to be lighted, while the gas burner, with its volume of light and of heat, must be further removed to be tolerable; and there is an actual requirement for more light from the latter than the former source to give the same effect in the room. The other substitute for the gas burner, the carcel-lamp, is frequently used in England as the centre-piece, singly or in numbers, of the tables in the dining room, drawing room, or library. Its illuminating power is about two-thirds that of a gas burner, and the quantity of heat given out bears very nearly the same relation, that is, the heat from a carcel-lamp is about two-thirds that from a single gas burner of 14 to 16 candle power. As the carcel-lamp is movable in a room, and is usually placed low down, the chance of the current of air proceeding from it defacing the ceiling, is much less than from a fixed gas burner, in its usual position of height from the floor.

What may be the exact physical or chemical conditions accompanying the manifestation of *bad* gas in England might call for a long discussion in reply. It can be said at once that the indications on the ceilings are almost entirely those of atmospheric impurities and condensation of water. Soot, dust and organic matter in suspension in a saturated humid air—wherein the humidity is the vehicle which carries these substances, and is not free to disperse them from the general saturation—will be and are deposited on the first object of cooling and contact. This view of the case is not a mere guess. The fact that there is a general discoloration of ceilings from gas burners in England, as contrasted with those of the continent, where the air is uniformly a little more dry, and where the use of bituminous coal is unknown, so that its particles of carbon dust do not form a part of the common impurities of the air; and also as contrasted with the ceilings in this country; this fact is certain, and from it the connection of pure air with the *cleanliness* of gas burning is made evident. While English gas is much more carefully purified and treated than any in the world, the standard of its excellence is not only the highest, but it is made strictly up to this standard. Yet any sulphurous or sulphuric acids which emanate from gas lights, are at

once absorbed by the vapor present, and if the atmospheric condition does not facilitate the diffusion of this vapor, these acids are retained in the ascending column to exert their energies on the objects of first contact, and afterwards retained in the room to act generally on any sulphur absorbent, colors or materials, as they do in England and do not in this country. It is probable in our climate, and in that of the continent, much of the humidity of combustion, and of the deleterious gases either evolved by, or inherent to, the illuminating gas—as well as the organic impurities, dust or soot, in the air burnt or heated by the act of burning—is diffused at once into the tenuious vapor of the surrounding air. Not only before passing four or five feet from the burner, so that no condensation takes place on the ceiling, but also so thoroughly diffused as to prevent, in great degree, those chemical actions which prove so objectionable from the burning of the best purified coal gas in England.

[To be continued.]

THE STRENGTH AND DUCTILITY OF IRON AND STEEL BOILER PLATE, AT DIFFERENT TEMPERATURES.

By Charles Huston.

The present law of Congress requires all makers of boiler plate for marine boilers, to stamp on their iron the number of pounds tensile strength it will sustain before breaking, making it obligatory on the inspectors of the several districts to see that the plates shall possess the strength stamped upon them, and also that they shall have the other qualities required by law, viz., homogeneousness, toughness, and ability to withstand the effect of repeated heating and cooling.

This, as will be seen, covers a *very large field*, and requires much experience and skill, on the part of the local inspector, in all the qualities of iron or steel that may be used in the construction of boilers; the mere question of tensile strength may not be very difficult to ascertain, but the question of "*homogeneousness, toughness, and ability to withstand the effect of repeated heating and cooling*," is a very different one, and involves a large degree of knowledge in

matters still in more or less doubt with the most eminent scientists of the day.

In order, therefore, to settle in my own mind, by practical tests, some of these questions, I have been led to make the following experiments, to ascertain the comparative strength and toughness of four different samples of boiler plate: 1, cold; 2, at 300° C. (572° Fahr.); and 3, at 500° C. (932° Fahr.); taking as my measure of *toughness* the degree of contraction of area at the point of fracture. I have taken nine pieces, each from the same plate: 1, *charcoal boiler plate*, made from the pile in the ordinary way; 2, a very exceptionally soft piece of Siemens-Martin steel; 3, a piece of ordinarily soft crucible steel, such as is generally used for boilers, and will not harden when heated and plunged into water; and 4, a rather harder piece of crucible steel, that will become more rigid when heated and plunged into water, but still soft enough to bend flat without breaking. Making three tests at the same temperature, enables us to form an approximate idea of the *homogeneousness* of each kind of plate, both as to tensile strength, and also as to toughness; but it will, of course, require a large number of tests to establish the correctness, or otherwise, of those I now have the pleasure of giving you.

The most troublesome question I had to contend with, was the best way to measure the temperature of the test-piece and maintain it, while the test was being made, but finally I adopted the following: I made the breaking point in the test-piece by taking a piece of the plate planed with parallel sides, about one inch wide, and in the middle drilled a hole about $\frac{2}{10}$ of an inch in diameter, thus,

thereby reducing the area of the test-piece at that as a breaking point. This hole I then filled with a plug of amalgam of known melting point—for 300° C. I used an amalgam of 32·3 tin and 67·7 lead, and for 500° C. I used an amalgam of 75·5 lead and 24·5 silver (see "Die Metallurgie, John Percy, übertragen und bearbeitet von Dr. F. Knapp und Dr. H. Wedding"). Having thus prepared the test-piece, it was fixed in the testing machine, and a full, large flame of a blowpipe, covering the whole width of the test-piece, was applied. As soon as the amalgam became *semi-solid* on the side opposite to

that on which the flame was directed, I kept it in that state while my assistants carried the strain up to the point of rupture.

1.—Charcoal Boiler Plate, Piled.

Tensile Strength.

Cold.	300° Centigrade.	500° Centigrade.
56,500	66,940	70,130
52,300	59,300	62,800
57,300	63,000	63,100
Average, 55,366	63,080	65,343
Percentage of gain, . .	13·93	18·02

Contraction of Area (Percentage).

Cold.	300° Centigrade.	500° Centigrade.
28	23.5	22
26	22.5	21
24	23.5	21
Average, . 26	23·17	21·33
Percentage of loss, . . .	10·88	17·69

2.—Siemens-Martin (Exceptionally Soft).

Tensile Strength.

Cold.	300° Centigrade.	500° Centigrade.
51,400	66,700	61,700
55,800	66,350	64,250
56,600	65,200	67,100
Average, 54,600	66,083	64,350
Percentage of gain, . .	21·03	17·86

Contraction of Area (Percentage).

Cold.	300° Centigrade.	500° Centigrade.
50	40	32
50	41	36
41	32	32·5
Average, 47	37·66	33·5
Percentage of loss, . .	19·85	28·72

3.—Crucible Steel (Ordinarily Soft).

Tensile Strength.

Cold.	300° Centigrade.	500° Centigrade.
61,600	66,800	65,400
68,000	68,600	69,600
62,400	72,400	70,800
Average, 64,000	69,266	68,600
Percentage of gain, . . .	8·23	7·18

Contraction of Area (Percentage).

Cold.	300° Centigrade.	500° Centigrade.
37	37	21
35	29	22
37	24	21
Average, 36·33	30	21·33
Percentage of loss, . . .	17·42	41·29

4.—Crucible Steel (Not Quite Hard Enough to Temper).

Tensile Strength.

Cold.	300° Centigrade.	500° Centigrade.
77,900	79,500	81,700
77,800	87,800	82,000
79,400	81,000	68,000
Average, 78,366	82,766	77,266
Percentage of gain, . .	5.62	
Percentage of loss, ...		1·4

Contraction of Area (Percentage).

Cold.	300° Centigrade.	500° Centigrade.
28	13·25	16·25
28	23·	22·
24	12·	22·
Average, 26·66	16.08	20·08
Percentage of loss, . .	39·69	24·68

The result of these few experiments would seem to show that in all the four samples of boiler plate there was a decided increase of tensile strength at 300° C., and a still continued increase at 500° C., in the charcoal piled iron, but a falling off at 500° C. in the Siemens-Martin and crucible steel in proportion to the probable amount of

carbon, in the case of No. 4 bringing the strength a little below that at the ordinary temperature.

In the contraction of area representing the *ductility* of the metal, there is a constant *decrease* the larger the percentage of carbon (as indicated by the degree of hardness), the greater the loss of ductility, except in the case of No. 4, which, from some cause, shows great irregularity when heated, averaging more at 500° C. than at 300° C.

These experiments are necessarily delicate, and require great care to avoid error in measuring the degree of heat as well as in the measurement of the test-pieces before and after being pulled. I have taken all the pains I could, and hope some more able, better qualified individual may pursue the investigation further, and either confirm or disprove what I have stated. If, however, the foregoing tests are correct, it becomes a serious question as to the practice of making steel boilers any thinner than those made from iron.

LUKENS' ROLLING MILL, *Coatesville, Pa., Jan. 10th*, 1878.

THE SEYSS AUTOMATIC WEIGHING AND SORTING MACHINE FOR COIN.

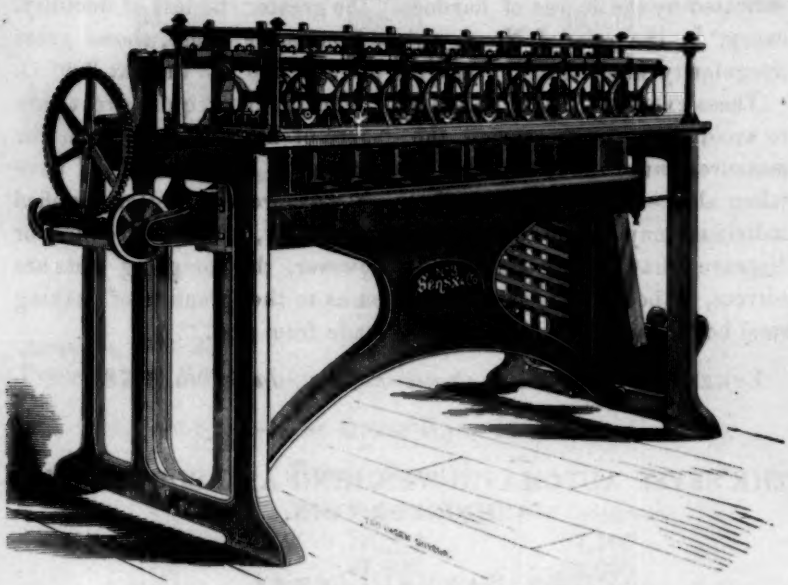
By SAMUEL JAMES.

This machine was designed and first built by Mr. Ludwig Seyss, at the request of the Master of the Imperial and Royal Mint in Vienna, who was desirous of obtaining a reliable automatic balance for the purpose of sorting the planchets used for coinage, into three separate classes, namely, those that were of the standard weight, those that were lighter, and those that were heavier than the standard. This classification was afterwards enlarged so that the machine was able to divide the heavy planchets into three separate classes, making the scraping or filing of the planchets to the standard weight of much more convenience.

All the working parts of the machine are supported on a frame of cast iron, as will be seen by Fig. 1. The power necessary to operate the machine, which has been estimated to be the one-tenth part of a horse power, is derived from any motor of a uniform and reliable motion, which motion is transmitted to the machine by the

means of a cord belt passing over the pulley on the shaft at the end of the machine, giving to the shaft a speed of 160 revolutions per minute. Upon this shaft is placed a worm, which gears into a wheel

Fig. 1.



upon the end of a shaft running in front of, and parallel with, the machine. The motion is, therefore, transmitted to this shaft, which has upon either end three cams, which, by the revolution of the shaft, transmit the motion to the other parts of the machine.

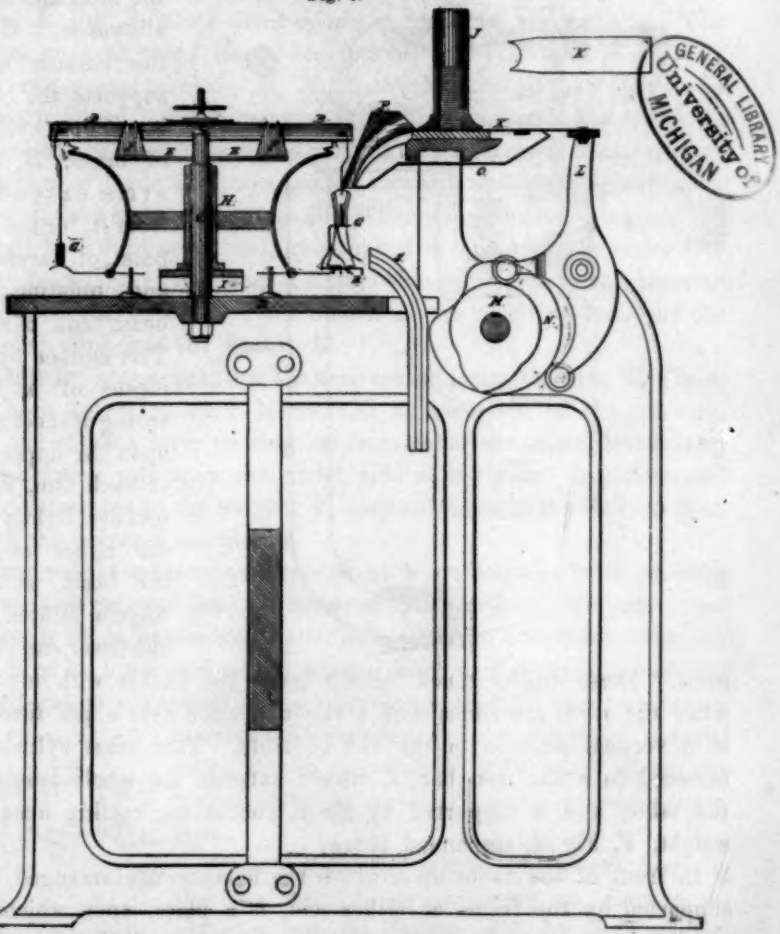
The construction of the balance is as follows: The beam, Fig. 2, is made of two thin plates of silver-plated steel, held together by suit-

Fig. 2.

able pins or supports, and is 30 centimetres long between the knife edges; the weight of the beam being 86 grammes, and each basket or pan 32·7 grammes, making the total weight of the beam and baskets 151·4 grammes. *GG*, Fig. 3, are the baskets, or pans, suspended at either end of the beam. The one at the right carries the planchet to be weighed, and the one at the left carries the weight to which it

should correspond. The centre knife edge rests upon an agate bed, and the baskets or pans are hung by agate bearings, on knife edges, at either end of the beam. The beam is readily adjusted by means of a small brass nut, which runs upon a screw fastened between, and parallel with, the steel plates of the beam; the sensitiveness of

Fig. 3.



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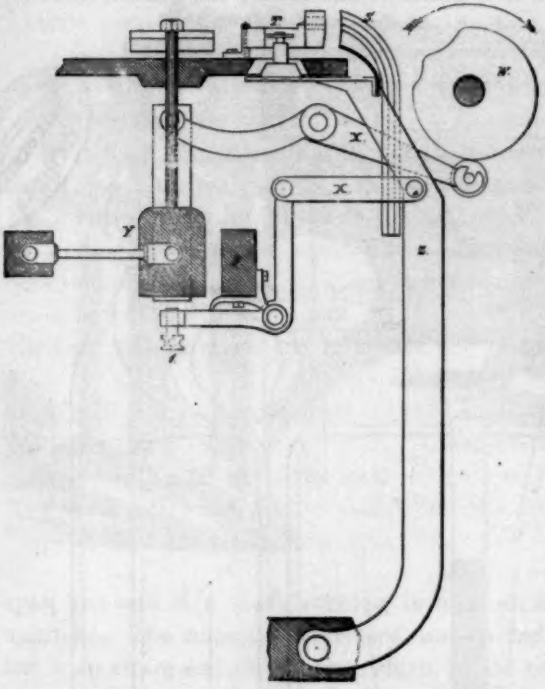
the beam being adjusted by a brass nut running upon a screw fastened in a vertical position over the centre knife edge. The balances, ten in number, are arranged upon a cast iron plate or table, supported at either end by the frame of the machine. Each balance rests by its centre knife edge upon a column, *C*, Fig. 3, screwed fast into the bed-

plate or table, *D*, and having horizontal arms upon its upper end. The horizontal arms support, at their ends, rests of thin steel cut V-shaped at their upper extremities, for the purpose of holding the small gold wire riders, used to mark the light and heavy allowance. Upon this column which supports the beam, is a sliding cylinder of brass, *H*, with arms extending from it, for the purpose of arresting and quieting the beam and baskets. This is done by the means of a light spring of sheet brass upon the upper end of each arm, which touches lightly under either end of the beam, and by fingers jointed into the lower end of the arms. These fingers touch lightly under the basket with one end, while the other end slides with a slight friction over a pin fastened in a vertical position in the bed or table. This brass cylinder is fastened to a flat iron bar, *I*, which extends the whole length of the table, and is supported by three iron stems, resting upon the weight, *Y*, Fig. 4, suspended below.

Fig. 4.



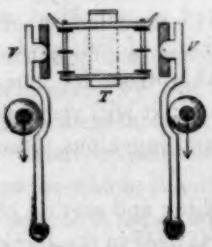
In front of the table upon which the balances are arranged, and supported by the frame at either end, is a plate, upon which are arranged the tubes or vertical cylinders of brass, *J*, Fig. 3, used to receive and hold the planchets, before being passed to the balances, and also the boxes, or compartments, *P*, into which each planchet is delivered, before being dropped into the basket for weighing. Under the bottom of each of these tubes or cylinders, is a flat slide of

steel, *K*, of the same thickness as the planchet to be weighed; the slides are cut out upon one end, in the shape of a semi-circle, so that they may slide up to the planchet, and push it from the tube into the receiving box, *P*, while the other end is made fast to a flat bar extending in front of, and parallel with, the plate supporting the tubes, and is fastened at either end upon the upper ends of levers, *L*, Fig. 3, which pivot upon the frame of the machine. The bottom ends of these levers are forked, and rest by friction rolls upon two separate cams, *M*, *N*, on the horizontal shaft driven by the worm wheel. These cams, as they rotate, act upon the levers, *Z*, causing a forward and backward motion. As they are moving forward, the slides, or feeders, *K*, are pushed forward, and, passing under the tubes, *J*, push a planchet out, so that it drops into the receiving box, *P;* in their backward movement, by means of a stop upon the under side of the feeders, they pull back a second slide, *O*, which to this moment has closed the opening at the bottom of the receiving box, and the planchet slips into the basket, *G*.

While the above operation has been taking place, the cam, *W*, Fig. 4, has been operating upon levers, *X*, at each end of the machine, one end of each lever passing out from under the frame, and resting by a friction roll upon the under side of the cam; the other end being connected to the weight, *Y*, suspended under the bed, *D*, upon which the balances are placed.

This weight rests upon one end of a rectangular lever pivoting upon a stud screwed into the frame of the machine. The other end of the lever is connected, by a link, *X'*, to a vertical lever, *Z*, which, at its lower end, pivots upon a stud in the frame; while the upper end is connected to, and supports, a plate upon which are fastened the delivery box, *S*, with its channel ways, as also the friction rolls which clamp the basket while the weighed piece is removed therefrom.

Fig. 5.

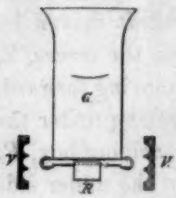


When, as before stated, the levers carrying the feed movements necessary to convey the planchet into the basket have, by their motion, deposited the planchet there, the third cam has moved so as to cause the brass clamps, *V*, Figs. 5 and 6, which, until this moment, have held the basket, to open and release their hold; while, at the same time, the brass cylinder, *H*, Fig. 3,

rises, and by the springs upon the upper ends of its arms, and the fingers upon the lower end, touches lightly the beam and baskets, quieting the same, and then immediately descends, allowing the beam to vibrate. The time allowed for the vibration is, in the case of those used in the Philadelphia Mint, five seconds.

As soon as the beam has assumed the position corresponding to the weight of the piece in the basket, the weight under the table, by the action of the cam, *W*, upon the lever, *X*, is lower upon the end of the rectangular lever, pressing it down, thereby moving the lever, *Z*, forward, causing the clamps, *V*, Figs. 5 and 6, to hold the basket in their grooves, and the slide, *R*, which closes the opening from the basket, is pressed back, and the planchet slips into the delivery box, and thence, through the channel ways, into the collecting boxes at the end of the machine.

Fig. 6.



When the planchet has passed from the basket, the weight, *Y*, commences to rise, and the vertical lever, *Z*, carrying the delivery box is forced back by a spring; as soon as it has moved far enough to allow the door from the basket to be closed, the next planchet is dropped in by the withdrawal of the slide, *O*, which closes the exit from the receiving box.

This machine was invented by Mr. Seyss, in the year 1871. Since then he has constructed 39, which are in use at the following mints: Vienna, Berlin, Kremnitz, Munich, Dresden, Hamburg, Stockholm, Copenhagen, Brussels, Darmstadt, Berne, Frankfort on the Main, Hanover, Costa Rica, and Philadelphia.

The first machine for this purpose was, as far as I am informed, invented by Baron Seguiers of Paris. Such a machine was ordered by the Government in the year 1852, and was received at our Mint in 1854; it was constructed for the weighing and sorting of half eagles only; the use of it was abandoned most probably from its incapacity to perform the work in a satisfactory manner; it still remains in the Cabinet of the Mint, and is a very pretty and ingenious piece of mechanism.

The only other practicable machine for the weighing and sorting of coins is that constructed by Napier & Sons, which is used in the Bank of England. It is worked by water power, and weighs 18 pieces

per minute, dividing the coins into three classes, while the Seyss machine will weigh 80 pieces, dividing them into the same number of classes.

By the introduction and use of the Seyss machine, the separate weighing of the silver coin will be accomplished, thereby preventing any silver coin passing from the Mint which shall not be within the legal allowance, viz., 1½ grains light or heavy on each piece. The large number of silver pieces annually struck has heretofore prevented the weighing of single pieces, but with the aid of a sufficient number of the Seyss machines it is thought this can be done. The capacity of this machine, as compared with the amount of work that can be accomplished by one person, is as one to five; therefore the machine, attended by one person, will perform, in a given time, the same amount of work that would, by the use of the ordinary balance, require the services of five.

REPORT ON A STANDARD WIRE GAUGE.[1]

The Committee on a Standard Gauge have been constantly engaged, since their appointment, in the duties assigned to them. They have corresponded with different persons interested in the manufacture and use of gauges in this country, and have received from several of them important information.

They have also entered into correspondence with the governments of England, France, Germany, and Russia, through their consuls, and with Austria directly. The consuls of Germany and France have taken the greatest interest in the matter, and have communicated to your committee a large amount of valuable information relating to the gauges used in their countries. Prof. Tunner, of Leoben, Austria, one of our honorary members, has communicated information relative to the uses of gauges in Austria. The replies to the communications addressed by the English and Russian consuls to their respective governments, have not, as yet, been received.

Your committee commenced its labors, having in view to find a gauge which should be simple in its construction, not readily worn, capable of easy adjustment, and not too expensive to be used by the

[1] A paper read before the American Institute of Mining Engineers, at the Amenia meeting, October, 1877.

ordinary workman. With this in view, they have examined a large variety of gauges, and believe that all those in general use in the United States have passed under their inspection.

We find, as the result of our examination, that, although there are a great number of patterns, most of the gauges in general use differ but slightly in principle. The different systems may be divided into two general classes. These are—*first*, fixed; and, *second*, movable gauges.

Of the fixed gauges, there are three general types. These are, first, those made with slots, open at one end, the sides of which are intended to be parallel, as the ordinary wire gauge; second, those made with round holes made in a plate, with or without a plug corresponding to each hole to check the size, such as the Whitworth gauge, and the Stubbs wire gauge, better known in this country as the "twist drill" gauge.

In both these kinds of gauges, the slots and holes are designated by numbers.

The third kind of fixed gauge consists of a V, either cut into a sheet of steel, or formed by placing two bars of steel together at one end, and leaving them open at the other a fixed distance.

Of the movable gauges there are two types: Sliding calipers with verniers, with or without a micrometer screw for adjustment; and the micrometer screw gauge.

Your committee find that the gauges which are characterized by round holes or slots, designated by numbers, are only approximately correct. They not only differ according as they are made by different manufacturers, but in a package of a dozen made by the same manufacturer there often were very perceptible and annoying differences. They find that in the gauges with open slots the sides are rarely parallel, and that there are even greater variations in them than in the gauges made with closed round holes without plugs. They find that the numbers affixed to the slots and holes vary so much, on account of the differences in the width of the slots and in the diameter of the holes, as to be a constant source of inaccuracy, uncertainty, and annoyance. This variation has, in certain cases, been found to amount to as much as 50 per cent. of the weight of different wires of the same number which have been examined. It is, therefore, impossible to make even an approximative comparison of sizes, unless, besides the number, not only the kind of gauge, but also the name of

the maker, is specified, and that even then this approximation cannot be relied upon when the gauges have been worn from constant use or bad tempering.

The best example of the round holes with plugs is the Whitworth gauge, which is made of a thick plate of tempered steel. Each hole of the gauge is provided with a hardened steel plug, which fits it exactly. In all the recent gauges of this kind the system of numbers is abandoned. The plug is made of a given diameter, which is stamped in figures on each one. These diameters, generally, vary by thirty-seconds, sixteenths, eighths, quarters, and so on, each size having a hole and plug of its own, so that a complete set will consist of as many holes and plugs as there are fractional parts. To obviate the difficulty of the indefinite repetition of the plugs, they are sometimes made so that when any two, or even three, plugs are placed together, they will exactly fit the hole corresponding to the sum of their diameters. This arrangement is made to insure accuracy, as the multiplication of a very slight error would prevent even two plugs from fitting the hole corresponding to the sum of their diameters. When well made, this gauge is an instrument of precision; but it is evident that, in order to have such a gauge even moderately accurate, it must be a very expensive instrument, and altogether beyond the reach of an ordinary workman, or even of a manufactory with small capital; and that from the indefinite multiplication of holes and plugs, it must necessarily be very cumbersome. When they are used, there must always be two such gauges, one for comparison and one for use, and when the gauge is only very slightly worn it ceases to be an instrument of precision, and is then open to all the objections of the ordinary gauge with fixed holes.

Your committee, very early in the course of their investigation, formed the opinion that no reliance whatever was to be placed on the numbers of gauges, as an indication of size, except for the individual gauge to which the number was attached; and that the only accurate and scientific way of expressing the size of an article to be gauged was by some expression of its diameter, which should be more exact than numbers, and which would allow of an accurate comparison of all the dimensions by whatever gauge they were taken.

Your committee are supported in this opinion by the present practice among some European manufacturers who have recently acted in this matter, who have decided that a given number on a gauge shall

correspond to a given diameter expressed in fractions of the legal standard of length of the country; but as, in all fixed gauges made for ordinary commercial use, the diameter can only be approximately expressed, neither the number nor the diameter is ordinarily correct, so that there is a double source of inaccuracy, as the number does not express the exact diameter, nor the diameter the number.

Owing to the great liability to error, and the impossibility of correcting it, even in the most elaborate forms of this kind of gauge, your committee, early in the course of its investigation, after having themselves examined a large number, and having had communicated to them the results of examinations made by others, dismissed this class as being unsuitable, either from their defective construction, the impossibility of adjusting them when out of order, or their great cost, from their consideration as a standard gauge.

Your committee next turned its attention to the V gauge, which is made by placing together two pieces of hardened steel, so that they touch at one end, but are open a given distance at the other, the numbers or diameters corresponding to the opening being graved upon one or both of their sides. The accuracy with which measurements can be made with this gauge when it is new, and the jaws properly tempered, adjusted, and fastened, is surprising. Exceedingly minute differences, even in the diameters of the same wires, can be detected and measured with great nicety, but by constant use the gauge wears unevenly. It must then be taken apart, reground, and readjusted, which will generally cost more than the gauge is worth.

Your committee, while having the highest opinion of it for ordinary purposes, after some months of study abandoned the idea of recommending it as a standard gauge.

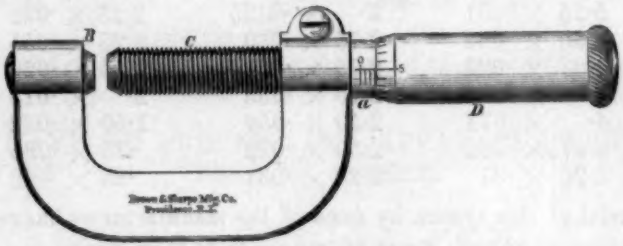
Their attention was then turned to the other two kinds of gauges, namely, the sliding gauge with a vernier, with or without a micrometer adjustment, and the gauge known as the micrometer gauge. The advantage of these gauges is great accuracy. The sliding gauge with a vernier necessarily wears, but the error of wear can be ascertained and allowance made for it, so that accurate measurements can always be made with it when it is worn.

In the micrometer gauge the wearing surfaces are so arranged that they can be adjusted with ease in a few moments. The wear between the male and female parts of the micrometer can be adjusted by a binding screw. This adjustment can be repeated as often as required,

so that the instrument will read with great accuracy until it is worn out.

Your committee assured themselves by actual trial that with such a gauge boys can very easily be taught to read the thousandth of an inch or the fortieth of a millimetre, and that it is practicable to read even the eightieth of millimetre.

The micrometer gauge is, of these last two gauges, the simplest. It consists of a micrometer screw, C, with a vernier attachment on D, is susceptible of easy adjustment, is not likely to wear, is not complicated, is less likely to get out of order than the other gauges, is more easily read, and requires less skill to read it than the sliding gauge with a vernier. Your committee are therefore of the opinion



that this gauge, which is shown in the above cut, is the gauge which should be adopted as the standard gauge.[1]

They are of the opinion that all gauges should be graduated so as to read fractions of an inch or of a millimetre, and that the sizes

[1] Description of the Gauge.—The piece in the form of the letter U has a projecting hub, *a*, on one end. Through the two ends are tapped holes in one of which is the adjusting screw, *B*, and in the other the gauge screw, *C*. Attached to the screw, *C*, is a thimble, *D*, which fits over the exterior of the hub, *a*. The end of this thimble is beveled, and the beveled edge graduated into twenty-five parts and figured, 0, 5, 10, 15, 20. A line of graduations, 40 to the inch, is also made upon the outside of the hub, *a*, the line of these divisions running parallel with the centre of the screw, *C*, while the graduations on the thimble are circular. The pitch of the screw, *C*, being 40 to the inch, one revolution of the thimble opens the gauge 1-40 or 25-1000 of an inch. The divisions on the thimble are then read off for any additional part of a revolution of the thimble, and the number of such divisions are added to the turn or turns already made by the thimble, allowing 25-1000 for each graduation on the hub, *a*. For example, suppose the thimble to have made four revolutions and one-fifth. It will then be noticed that the beveled edge has passed four of the graduations of the hub, *a*, and opposite the line of graduation will be found on the thimble the line marked 5. Add this number to the amount of the four graduations, which is 100-1000, and it equals 105-1000, which is the measurement shown by the gauge.

should be expressed as the only means of insuring correct measurements, and not by numbers, which constantly lead to error. That this, while it insures great accuracy, presents no difficulty in practice, is shown by a number of experiments made during a period of several months, to ascertain the practical difficulty in the way of the adoption of this method by a member of your committee. The sizes of some of the steel bars, the orders for which were expressed in thousandths of an inch, are given below.

Sizes expressed in decimals of an inch, taken at random from the order book of a manufactory which has adopted this method:

15·5 × ·014	3·00 × ·0145	2·25 × ·059
15· × ·02	3· × ·018	2·25 × ·046
15· × ·014	3· × ·02	2·25 × ·040
5·25 × ·061	3· × ·0125	2·25 × ·038
4·50 × ·062	2·75 × ·030	2·25 × ·055
4· × ·024	2·75 × ·051	2·25 × ·020
4· × ·022	2·75 × ·035	2· × ·018
4· × ·071	2·50 × ·059	1·50 × ·032
3·475 × ·062	2·50 × ·022	·75 × ·095
3·25 × ·01	2·25 × ·031	·25 × ·062

The trial of this system by some of the manufacturers has resulted in banishing all the old forms of gauges from their workshops.

The conclusions which have been arrived at, for the most part independently, by the different members of your committee, and in which they unanimously agree, are:

1. The abandonment of the system of fixed gauges for commercial use.

2. The abandonment of the system of representing the diameters and sizes by numbers.

3. The adoption of the system of expressing sizes in thousandths of an inch or fractions of a millimetre.

4. The adoption of the micrometer gauge as the method of measuring sizes.

Your committee beg to acknowledge their indebtedness to J. B. Knight, Secretary of the Franklin Institute, in Philadelphia, for the reports of various committees on gauges of the Franklin Institute; to C. Hewitt, Esq., President of the Trenton Iron Company, for a large number of measurements of wire made with different gauges; to P. Ritter von Tunner, of Austria, for the description of the kind of gauges used in Austria; to the German Consul, for his interest in procuring from

Germany a report of their gauge system; to the French Consul, for his interest in the work of the committee; and to the Minister of Agriculture, Commerce, and Public Works, for a complete description of the gauge system as used in France.

Your committee is, however, particularly indebted to Darling, Brown & Sharp, of Providence, who have loaned to them, without charge, all the gauges which they manufacture, for comparison, and have contributed besides a very large amount of information on various matters connected with this subject.

All of which is respectfully submitted.

T. Egleston, *Chairman.*
Wm. Metcalf.
Jos. D. Weeks.

THE HAYFORD PROCESS AND APPARATUS FOR PRESERVING TIMBER.

By Edward R. Andrews, of Boston.[1]

Mr. President and Gentlemen, Members of the Franklin Institute:—I wish to invite your attention, this evening, to a consideration of the natural and mechanical principles involved in the "Improved Processes and Apparatus for Preserving Wood," patented by Ira Hayford, Boston.

As introductory to the main subject, a few statistics of the rapid consumption of the timber of this country, an explanation of the causes of decay in wood, and the scientific principles which are the basis of every successful method of arresting and preventing decay, will not be out of place.

The subject of *wood-preserving* has not received the attention of scientific and practical men in this country, which its importance as a valuable industry demands for it. In Europe it is not only well understood, but preserved wood is generally used.

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[1] Paper read before the Franklin Institute, January 16th, 1878.

Maxime Paulet, a French chemist, in a large octavo volume on this subject, published in 1874, mentions not less than 173 different processes and apparatus, which have been patented or described in scientific works since the year 1700.

The most valuable systems were discovered between 1832 and 1838. Kyan, Bethell, Burnett, and Boucherie—whose names have been given to the methods employing corrosive sublimate, creosote, chloride of zinc, and sulphate of copper—introduced their several systems during that short period. All of these are in use in Europe, and scarcely any others, three of them, to a very limited extent, in this country.

In Europe, the use of preserved timber is the rule; here, it is the rare exception. Abroad, no question arises as to using preserved wood, and seldom as to the method; except in France, where sulphate of copper is largely used for railway ties, the Bethell system, or the impregnation of the pores of wood with the heavy oils of tar, known as creosote oils, has almost entirely superseded every other system.

In this country, the apparently inexhaustible supply of timber has retarded the general use of preserved wood. Yet, for some years, it has become evident that our supply is not inexhaustible. The drain is enormous; many parts of our country have been stripped of forests altogether. The statement is made, in *Scribner's Monthly* for December, that the annual lumber product of the whole country is ten thousand millions of feet. A very considerable portion of this product is to replace what was cut four to ten years before, and has decayed.

Consider for a moment the consumption of wood in the one item of railroad ties. Massachusetts, employing mostly chestnut ties, which last on an average six years, uses up in this way, annually, a volume of lumber nearly equal to the whole product of Maine; and the 80,000 miles of track in the whole country, allowing four years as the average life of ties, actually use up in ties alone one thousand six hundred millions of feet annually, or equal to one-sixth of the timber product of the whole country.

Add to this the consumption of wood for fences along the lines of railways, the bridges, platforms, etc., and it is easy to see that if some effort be not soon made to lengthen the life of railroad timber, the supply will become insufficient.

There are also 76,000 miles of telegraph poles, requiring for their renewal annually 43,620,000 feet of wood, or nearly equal to the product of the State of Maine. Telegraph poles were first creosoted in England, twenty-seven years ago, and are as sound as at first, to-day. The English government is now creosoting all the telegraph poles in the United Kingdom.

In view of these facts, added to the cost of labor attending the renewal of decayed wood, it would seem that this country ought to be alive to the importance of preserving wood, in view of the results of European experience.

I do not find there is any lack of interest in this subject, only a lack of knowledge and of faith. That there is a lack of faith is not strange, because, as a rule, preserving has not added much to the life of timber in this country. This is, no doubt, partly due to the fact that those who have constructed works here, have put up a flimsy structure to fill some contract, or had some stock-jobbing operation in hand, but also partly to the fact that the systems in use abroad are not fully adapted to meet the wants of this country.

Had either European system been so, it certainly would have become general ere this. Our railroad engineers would not have continued the use of natural wood for ties, which last only four to six years, if through the use of the Bethell system their life could have been increased to twenty or thirty years, as in England.

Here let us consider what decay in wood is, what it is caused by, and what is needed to prevent it. There are two kinds of decay, known as *Wet Rot* and *Dry Rot*.

Wet Rot takes place in wood containing sap, which is exposed to moisture. It often commences in a living tree. It shows itself in the red streaks in the wood when felled, and woodmen recognize its existence even before the tree is cut down. It is wet rot which destroys railroad ties, fence posts, telegraph poles and bridge timber. It is hastened by alternate moisture and dryness.

Dry Rot, so called, needs moisture for its development as well as wet rot. It occurs in close, confined, damp localities, where there is imperfect ventilation. As a rule, it flourishes most actively in unseasoned lumber, but it also attacks seasoned lumber, when so placed that it can absorb moisture from its surroundings. *Dry Rot* is that sort of decay which is found in cellars and basements, between the

ceilings and floors of houses, etc. Wood used in such localities is often already in a state of decay when placed there. It comes by cars or vessel direct from the saw-mill, and is framed at once, reeking with sap and moisture.

It is dry rot which destroys vessels, owing to confined air; the short life of wooden vessels is mainly attributable to this cause, and several of the methods for preserving wood were first used to prevent decay in the British Navy.

In localities where dry rot exists, and has destroyed one set of timbers, the seeds of decay are there still, ready to attack new timbers, unless the conditions can be entirely changed by ventilation or otherwise, and often such a change is impossible.

What is the cause of wet rot and dry rot? It is due primarily to the fermentation of the albumen of the sap, which commences as soon as the necessary conditions, heat and moisture, are provided. In a living tree, the unmatured sap rises from the ground through the sap wood, and after being transformed by the action of the leaves into true sap for the formation of woody fibre, it descends within the bark loaded with sugar, acids, albumen, etc., and forms the annual growth of wood, holding in abundance rich sap within its cells and fibres. So long as the tree lives, these processes go on naturally, but when the tree is cut down, and the leaves no longer perform their functions, the abundant sap clogs the pores, and is in a favorable condition to be acted on by heat, and begins to ferment.

Fermentation causes the rapid development of countless myriads of spores of fungi always present. Animalculæ and insects follow, and the woody fibre is in time disintegrated, and although perhaps retaining the form of wood, it has lost all its strength and tenacity, and crumbles into pieces at the slightest blow. Rot is, then, the growth and development of fungus and animal parasites.

Preserving Processes.

The prevention of the development of fungus, or its destruction with the animal life it nourishes, is, then, the object of the various processes for preserving wood. The coagulation of the albumen of the sap is the only result obtained by the use of the metallic salts. Coagulation prevents the albumen from fermenting, and the spores of fungi lie dormant; both vegetable and animal life are arrested. As

a protection against dry rot, where wood is not exposed to moisture, these systems are useful, but when wood is exposed to water, they are of little value, as a rule. They consist in impregnating the pores of wood with watery solutions. It is certain they will partially redissolve by water, and leave the wood unprotected, always liable to absorb water carrying with it destructive elements.

It is important, then, that the public should not confuse creosoting with Burnettizing, etc. They only act chemically upon the sap, but creosote oil, containing carbolic acid, cresylic acid, etc., not only produces the same result chemically, but also secures *dryness*. Creosoting fills the pores of wood with an insoluble oil, and covers the fibres with a film, which protects them from absorbing destructive elements from extraneous sources. The oil, which saturates the sap wood, and the outer pores of the heart wood, resinifies and hardens under the action of the air, and forms a waterproof and air-tight covering to the wood. If the heart wood be not too dense, it also absorbs a large quantity of oil, otherwise the oil absorbed by the sap wood works inwardly, being very penetrating in its character, and, in time, can be plainly seen through the whole tissue.

It is *dryness*, then, and the waterproof and air-tight qualities imparted to wood by its impregnation with creosote oil, which give it its superiority over every other substance used for preserving wood. The presence of heat and moisture is necessary to induce decay; heat without moisture is harmless. Wood absolutely dried by some artificial process of desiccation will not decay, if it can be kept perfectly dry afterwards; hence, wood, which has been dried, has been preserved. Wood once dried, and then so protected that it can under no circumstances absorb moisture, has been rendered practically imperishable, except from wear.

When wood has been treated by the Bethell system, if the work has been faithfully done, it will not absorb moisture, and is, therefore, well preserved against decay.

Why, then, is not the Bethell system sufficient, you will ask? The answer is simply because only dry wood can be effectually treated by the Bethell process, and in this country we must treat green lumber. No system of wood-preserving can be made practicable here, which does not embrace some effectual method of drying green wood rapidly.

This defect of the Bethell system has always been recognized in Europe, where ties and timber intended for creosoting, are stacked up from nine to twelve months to season.

At a discussion on the preservation of telegraph poles, in 1876, Mr. Braine, Superintendent for J. Bethell & Co., London, made these remarks: "Dryness is the principal quality required in timber that is to be creosoted. Timber is sometimes delivered *dripping wet*, and the creosoting firm expected to creosote it without delay. * * * * * It is perhaps better that timber should not be creosoted at all than creosoted moist."

With us timber is used directly from the cars or vessel. We cannot wait for timber to season. It is not cut from the log until needed for construction. We must be prepared to take timber as it comes from the saw-mill, and in a few hours season and preserve it.

The Bethell system will not do this; oil and water will not mix together. So long as the pores of wood are reeking with sap and river water, it is impossible to inject into them any preservative substance. Hence, it is evident that the Bethell process needs some radical modifications before it can be adapted to the wants of this country. These modifications are precisely what have been made in the *Hayford* patents.

The important claims of the Hayford process are: *Dryness* before impregnation with any preservative substance, a complete coagulation of the albumen of the sap by heat, the evaporation of the watery portions of the sap, and the withdrawal of all moisture, sugar, acids, etc., in vacuo, leaving a pure wood fibre, fully preserved against decay, except from contact with air and moisture. There is no patent for the use of creosote oil. The Hayford patents cover improved processes for preparing wood to receive any preservative substance required, and apparatus for injecting such substance into the pores of wood thoroughly and rapidly.

Apparatus.

I will now describe, as clearly as I can, the apparatus used in the Hayford process, and then try to show wherein it brings about the results I claim. The apparatus is simple and strong. At my works at South Boston, I have endeavored to have perfect security from accident, and, at the same time, the best-fitted and strongest plant ever erected for wood preserving.

It consists mainly of an 85-horse boiler, a pump, a tank to contain oil, and a cylinder in which the wood is treated. The *cylinder* is the most important part of the works, and upon its perfect construction depends the commercial success of the enterprise. It is 100 ft. long, 6 ft. in diam., made of $\frac{1}{2}$ inch boiler iron steam riveted. On either end, a cast gun-iron ring is riveted, which serves as a jam to a wrought-iron door made of plates $\frac{5}{8}$ inch thick, bent to a semi-globular form and riveted to a gun-iron ring of same dimensions as the ring on the cylinder. This door is hung to the cylinder by a hinge, which, however, acts as a guide only, the weight being supported by a strong wheel, which rolls on a track with a solid foundation. A rubber gasket makes the joint between the rings perfectly tight. The cast-iron rings are pierced with bolt holes, through which 36 bolts pass. On one end of each bolt is a case hardened nut, and at the other is pierced an eye, into which slips one of a series of steel keys, arranged upon a ring, which revolves about the cylinder by a screw motion, by which means all the bolts are fastened or unfastened at once. It is necessary to give a few turns to the nuts with a wrench, to make the joints perfectly tight, before commencing a treatment, or to loosen the strain when the treatment is over, and the doors are to be opened; but by this simple mechanical contrivance, the great labor of opening and closing the doors is made comparatively easy.

The cylinder rests on rollers, to allow for expansion and contraction, supported on brick piers. This cylinder is a perfect piece of boiler work, and has been tested by hydrostatic pressure of 200 pounds to the square inch. There is no leakage during the process, when the pressure reaches from 100 to 150 pounds. Great annoyance has been frequently experienced with cylinders made for wood preserving on account of leakage, and danger also from want of strength in the heads, generally of cast iron, which broke under the required strain.

A railway track, 3 feet 4 inches wide, runs through the cylinder, and extends 100 feet beyond at either end, so that iron cars can be loaded with lumber at one end and be discharged at the other. Between the tracks, at the bottom of the cylinder, lies a coil of steam-pipe 1400 feet long, which connects with the boiler at one end, and at the other has outlets both with the outer air and with the inside of the cylinder, that the steam, after passing through the coil, can be allowed to escape into the cylinder when desired.

A series of perforated pipes is arranged around the inside of the cylinder, for the purpose of introducing the oil. These are connected with the oil tank. They are so arranged that, when the oil is let on through them, every stick of wood in the cylinder is at once bathed with oil.

The *oil tank* is simply a receptacle to contain the oil, and of capacity sufficient for the purpose. It is strong enough to stand a pressure of 100 pounds to the square inch. A coil of steam-pipe, connected with the boiler, is laid through it for the purpose of heating the oils to the required fluidity.

A simple, but powerful, pump is so provided with valves and pipes that by opening one set of valves and pipes it is a force pump, and by closing these and opening another set it becomes a vacuum pump. A water-jacket around the air-chamber keeps it cool while in operation. The necessary piping to connect the parts together completes the apparatus.

Hayford Process.

The first part of the process is for the purpose of drying the timber.

The wood to be treated has been placed upon iron cars, and run into the cylinder, which is hermetically closed. Steam is then admitted through the coil in the cylinder, and after passing through the coil, it escapes into the cylinder itself. The temperature in the cylinder very soon reaches 180° Fahr. It rises very slowly from this point, the evaporation of the sap and moisture in the wood tending to cool the temperature. It is best that the heat should increase gradually and that it should be kept moist. If allowed to be too dry, the outer fibres of the wood naturally harden, and thus prevent the escape of the moisture within. To avoid this, and also to save all the heat, the exhaust from the pump is also admitted into the cylinder. The pump is set at work to force atmospheric air into the cylinder, until the pressure gauge shows a pressure of 30 to 40 lbs. to the square inch. The object of this is to keep the wood from checking; green wood, in large dimensions, when exposed to high temperature, has a tendency to check. A vacuum forms about the wood, arising from the condensation of steam, and the expansion of the moisture within the wood tends to throw apart its fibres. This tendency is counteracted by the atmospheric pressure above stated.

And thus a higher degree of heat can be used in drying the wood without injury to its fibres. 250° to 270° are sufficient to evaporate the sap.

During the steaming process, a pipe in the bottom of the cylinder is kept open, to allow the escape of the condensation. By the same means is maintained a current of hot air, which is very efficacious in drying wood. The time necessary for drying wood in this process depends upon the quantity of moisture to be got rid of, and the size of the timber. Four or five hours suffice for boards and 2-inch plank, while ten or twelve are required for heavy timber.

Albumen coagulates at 140°, so that that result—the only one claimed for the Burnettizing and Kyanizing processes—is easily secured; but the sap and moisture cannot be got rid of, until they have been turned into vapor. Hence the necessity for continuing the steaming process until it is certain that all the portions of the wood containing sap and vapor have been heated to above 212°.

When this point is reached, the direct steam is cut off, all valves opened, and the air pumps kept at work to drive from the cylinder all the steam, vaporized sap and condensation, which remain in the cylinder; in other words, to free the cylinder entirely. This occupies about an hour, and closes the second part of the process. Heat is constantly maintained through the radiation from steam coil. We then commence to pump a vacuum.

The cylinder is once more made tight. The valves in the pipes connected with the pump, which made it a force pump, are closed; and those opened, which change it into an exhaust or vacuum pump. The vacuum pump is then set to work. There is, at this time, no appreciable amount of moisture in the cylinder, except what exists in the pores of the wood in the form of vapor. The vacuum pump has worked but very few minutes, however, when the vapors, partly condensed in the pump, begin to pour from the nose of the pump, and they continue to come for hours, filling, if the wood be green, many barrels with sap.

This shows the effect of the steaming process. If a cold vacuum had been pumped, when the cylinder was first closed, it could be easily done in less than an hour, but no water would have come through the pump, and the wood would not have parted with its sap. It is a common mistake to suppose that a vacuum alone will withdraw sap from wood. But after steaming, when the sap has been

turned into vapor, then it is drawn out by the force of the vacuum pump, yet the vacuum is reached very slowly, on account of the vast quantity of moisture which is drawn from the wood; five or six hours often elapse before the vacuum gauge indicates 24 or 26 inches of vacuum. But the sap having been withdrawn, the vacuum extends into the interior of the wood, if it can be properly so expressed, so that when the oils are let in, they are absorbed into the very heart of the wood.

This brings us to the last step in the Hayford process, namely, the impregnation with the preserving material. During the drying process, steam has been admitted to the coil in the oil tank, bringing the temperature up to about boiling point, to render the oils very limpid and penetrating. Creosote oil is heavier than water, weighing about 9½ pounds to the gallon, it congeals at about 60°, so that heat is needed to make it flow freely.

Impregnation.

I have previously explained to you that the oil is admitted to the cylinder through a series of perforated pipes, arranged around the inside of the cylinder. A pressure of about 60 pounds to the square inch is brought to bear upon the top of the oils in the oil tank; this pressure, together with the drawing force of the vacuum, make a force of about 75 pounds to the square inch, with which the oils are sucked and driven into the cylinder. Every stick is at once bathed with oil. The wood—being in a soft, somewhat spongy condition, the fibres porous, and the pores open—absorbs at once the hot, penetrating oil. If the wood be of a porous character, like pine, it absorbs all the oil required with the first flowing over of the oils, without any pressure; but if the fibre be solid and close, and the timber of large size, a further pressure of from 60 to 150 pounds is needed during a certain length of time to make the impregnation complete. But the wood having been put into a condition to absorb the oil, the impregnation is more rapid and more thorough than by the Bethell process, where no other means are relied upon than a pressure upon hard, air-dried timber in a cold vacuum.

The process is now completed, and the doors at either end being opened, the lumber treated is withdrawn, and another charge takes its place.

[To be Continued]

LIQUEFACTION OF OXYGEN.[1]

Translated by W. H. GREENE, M. D.

At the séance of l'Academie des Sciences of December 24th, M. Dumas presented the results of independent experiments of MM. L. Cailletet and Raoul Pictet upon the liquefaction of oxygen. He first read the following passages from Lavoisier, justly considered by the French savants as the founder of chemistry:

"Let us consider for a moment the condition of the different substances which compose the globe, if its temperature were suddenly changed. Suppose, for instance, that the earth were suddenly transported to a much warmer region of the solar system, to a region, for example, where the temperature is much higher than that of boiling water; in a short time, water and all of the liquids capable of vaporization at a temperature near that of boiling water, and even many metallic substances, would expand and become transformed into aeriform fluids, which would then become part of the atmosphere.

"By a contrary effect, if the earth were suddenly transferred to an intensely cold region, for example that of Jupiter or Saturn, the water which now forms our rivers and seas, and probably the greater number of liquids with which we are acquainted, would be transformed into solid mountains. * * * *

"Under this supposition, the air, or at least a part of the aeriform substances which compose it, would cease to exist in the state of invisible fluids, the proper amount of heat being wanting; it would therefore assume the liquid state, and this change would produce new liquids of which we have no ideas."

The priority of the discovery of the liquefaction of oxygen unquestionably belongs to M. L. Cailletet, but the researches of M. Pictet are much more thorough. The following extracts from his paper, which was presented by M. Dumas, give his results.

If pure oxygen or oxide of carbon be enclosed in a tube of the form which I have described,[2] and placed in the compressing apparatus which was operated before the Academy[2]; when the gases are cooled to — 29° by the aid of liquid sulphurous anhydride, both retain the gaseous condition. But if the pressure be suddenly relieved, that

[1] *Comptes Rendus*, lxxxv, p. 1212.

[2] *Comptes Rendus*, lxxxv, p. 851. Also see page 127, this No.

which according to the formula of Poisson should produce a temperature at least 200° below the starting point, an intense mist immediately appears in the tube, produced by the liquefaction, and perhaps the solidifaction of the oxygen or oxide of carbon. * * * *

This mist is produced by oxygen, even at the ordinary temperature, provided that time be allowed that it may lose the heat which it has acquired by compression alone.

These experiments were repeated in the presence of a number of scientific men on Sunday, 16th of December, 1877, at the *chemical laboratory of the École normale superieure.*

The following is a description of the apparatus and method of M. Raoul Pictet, of Geneva, whose results were obtained at about the same time.

A and *B* are two compound exhausting and compressing pumps, so coupled that while one exhausts, the other compresses, and that there may be the greatest possible difference between the effects of exhaustion and compression. These pumps operate upon liquid sulphurous anhydride contained in the annular recipient *C*. The pressure in this receiver is such that the sulphurous anhydride evaporates at a temperature of —65°.

The sulphurous anhydride thrown out by the pumps is conducted into a condenser *D*, cooled by a stream of cold water; it there liquefies at + 25° and under a pressure of $2\frac{3}{4}$ atmospheres. The liquid anhydride returns to the receiver *C* by a narrow tube *d*, as it is condensed.

E and *F* are two pumps precisely like the preceding, and coupled in the same manner. They operate upon liquid carbon dioxide contained in the annular receiver *H*. The pressure in this receiver is such that the carbon dioxide evaporates at —140°.

The carbon dioxide thrown out by the pumps is forced into the condenser *K* surrounded by the receiver *C*, cooled by the sulphurous anhydride, and which is at the temperature —65°. It there liquefies under a pressure of 5 atmospheres.

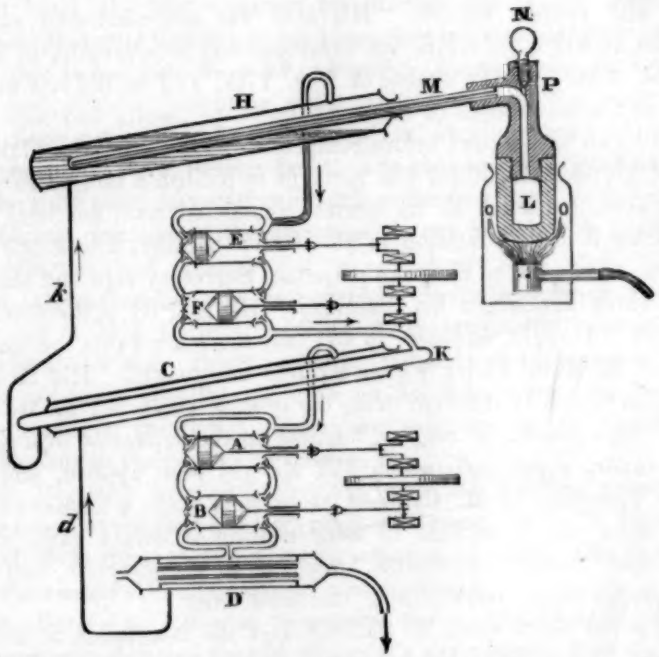
The carbon dioxide returns to the receiver *H* by the narrow tube *k* as it is liquefied.

L is a wrought-iron retort, thick enough to resist a pressure of 500 atmospheres. It contains potassium chlorate, and is heated so that pure oxygen is disengaged. It communicates by a tube with the tube *M* of very thick glass and 1 metre long, which is surrounded

by the liquid carbon dioxide in the receiver *H* at a temperature of —140°.

An iron plug screwed into the tubulure of the retort, permits the uncovering of an orifice *P*, open to the air. After the apparatus has been in action several hours, the pumps being worked by a 15 horse power engine, and when all of the oxygen has been disengaged from the chlorate, the pressure of the gas in the tube is 320 atmospheres, and its temperature —140°.

Fig. 1.



On suddenly opening the orifice *P*, the oxygen escapes with violence, producing an absorption of heat sufficiently great, that a part of it liquefies and appears in the tube, and is thrown out of the orifice if the apparatus be inclined.

It should be added that the quantity of liquid oxygen contained in the tube 1 metre long and 0·01 metre in internal diameter, occupies a little more than one-third the length of the tube, and was thrown out in a liquid jet from the orifice *P*.

[As a supplement to Dr. Greene's communication, we add the following extracts from the *Comptes Rendus.*]

M. Dumas, after analyzing the notes of Cailletet and Pictet, read a letter which Cailletet had addressed, on the 2d of December, to M. H. Sainte-Claire Deville, and which Deville had deposited on the next day, as a sealed package, with the Secretary of the Academy.[1]

M. Deville added the following explanation:

"M. Cailletet repeated his experiments on the condensation of oxygen in the laboratory of the Normal School, on Sunday, Dec. 16th, with perfect success. His note was not published earlier, because he was a candidate for corresponding membership, to which he was elected at the sitting of Dec. 17th, and he did not wish to urge any consideration of his work until its results had been confirmed by an experiment before competent judges. On the 17th, the day of his election, it did not seem fit to publish a fact of so great importance, inasmuch as the secret committee had not been able to discuss it in their session of the 10th; happily, I took the precaution, on the 3d, to have the perpetual Secretary sign and seal the letter which announced his discovery. His priority is therefore undeniable. I ought, however, to add that the remarkable accomplishment of M. Raoul Pictet is none the less meritorious. His mode of operation is totally different from the process employed by M. Cailletet. The process of cooling, founded on the expansion of a gas or of a vapor, a principle which had not yet been applied, and the simple apparatus of M. Cailletet, allow us to make a lecture experiment upon the resistance to condensation of divers gases which have been thought incoercible, which is very instructive, and very valuable for future researches of the same order.

"It is ten years since M. Cailletet laid the foundation of his discoveries. Desiring to obtain, under all circumstances, precise and rigorously measured results, he long since prepared special manometers, which he described in our *Comptes Rendus*, and he studied carefully the thermometric apparatus of M. Regnault and M. Berthelot. For this reason he now speaks, with well-grounded reluctance, of pressures determined by metallic manometers, and of temperatures marked by alcohol thermometers. Were it not for these absorbing

[1] The note contained the announcement which is embodied in the "Items" in this number of the JOURNAL.

studies, relative to the precision with which he wished to express the result of his experiments, he would long since have demonstrated the facts which he has published about gases, especially those relative to nitric oxide, carbonic oxide, and oxygen."

M. Jamin stated that the possibility of liquefying or solidifying oxygen is now demonstrated; the two experiments establish it; that of M. Pictet adds little to that of M. Cailletet, for if the former announces that he has seen oxygen in liquid form, everything seems to indicate that the sight was a very transient one. On the other hand, the mist observed by M. Cailletet at the moment of the escape, shows that the oxygen ceased to be transparent or gaseous, and that it had become solid or liquid. To have seen the liquid or the mist, without collecting either, is substantially the same thing. The final experiment is yet to be made; it will consist in keeping oxygen liquid at its boiling point, as in the case of nitrous oxide, or in the solid state, like carbonic acid, preserving itself in one of these conditions, because of the enormous latent heat which gasification requires.

M. Dumas added that he regarded the independence of the researches of MM. Cailletet and Pictet as satisfactorily established; pursuing the same object, creating methods and apparatus, which were not easily thought out, each on his side arrived at the same result, without knowledge of the other's labors, an occurrence which is frequent in the history of science.

M. Regnault informed the Academy that he was present five years ago, at the first attempts made at Geneva, by M. R. Pictet, and by M. de la Rive, to obtain the liquefaction of gases. He was struck by the remarkable ingenuity of the apparatus.

M. Berthelot, without forgetting the originality of M. Pictet's experiment, observed that M. Cailletet's experiments were the necessary results of his researches on the liquefaction of acetylene and nitric oxide, published in the *Comptes Rendus* (sittings of Nov. 5th and Nov. 26th). He called special attention to one circumstance of Pictet's remarkable experiment. The decomposition of chlorate of potash into oxygen and chloride of potassium, is not stopped by a pressure of 320 atmospheres. It is probable that the velocity of the reaction is changed, and, perhaps, also the temperature at which it is accomplished; but the reaction itself does not cease. This is a new proof in support of opinions already announced by him upon this important

question of chemical physics, opinions which were at first contested, but which new observations are continually confirming.

At the close of the sitting, M. Dumas received a copy of the following telegram:

"*Geneva*, 24 *December*, 4 *h.* 15 *m.*, *P. M.*

"Second experiment perfectly successful. Many spectators. Same to-day as Saturday. Inform M. Dumas.

"PICTET."

On Wednesday, the 26th inst., M. Dumas received the following letter:

"I received yesterday, from Paris, a telegram announcing the kind interest that you have taken in the announcement of the liquefaction of oxygen, which was accomplished on Saturday last in my laboratory.

"I especially desire to thank you for communicating the result, yesterday, to the Academy of Sciences, before receiving the complementary details, which I now furnish you.

"The result at which I have been aiming for three years, is the experimental demonstration that molecular cohesion is a general property of bodies, without any exception. If permanent gases could not be liquefied, it would be necessary to conclude that their constituent particles have no mutual attraction, and, therefore, escape this law. In order to bring the molecules of a gas as near together as possible, and thus to liquefy it, the following conditions are indispensable:

"1. To have the gas absolutely pure. 2. To be able to dispense with extreme pressures. 3. To obtain an intense cold, and a subtraction of heat, at these low temperatures. 4. To secure a great surface of condensation at these low temperatures. 5. To be able to use the expansion of gases from the great pressure to the atmospheric pressure, an expansion which, when added to the foregoing conditions, compels liquefaction.

"With the fulfilment of these five conditions, when a gas, under a pressure of 500 or 600 atmospheres, is maintained at a temperature of $-140°$ or $-150°$, and is suddenly allowed to expand to the atmospheric pressure, one of two things is necessary: either the gas liquefies under the law of cohesion, and yields its heat to the portion of gas which expands and escapes in gaseous form; or, if the law of cohesion is not universal, the gas must pass through the absolute

zero. In other words, it must be inert, dust-like, without consistency. The work of expansion would be impossible, and the loss of heat, absolute.

"Convinced of this reality, which thermodynamic equations assert by conclusive figures, I have sought to contrive a mechanical arrangement which would satisfy these divers conditions, and I have fixed on the following:

"I take two suction and force pumps, such as I use in my ice apparatus, and couple them so that the exhaust of one corresponds to the compression of the other; the exhaust of the first communicates with a tube $1{\cdot}10^{m}$ long, and $12{\cdot}5^{c}$ in diameter, filled with liquid sulphurous acid. Under the influence of a perfect vacuum, the temperature of this liquid quickly falls to — 65°, and even, in extreme cases, to 73°. Within this tube of sulphurous acid passes a second tube, having 6 centimetres exterior diameter, and the same length as its envelope. These two tubes are connected at bottom. In the central tube I compressed carbonic acid, prepared by Carrara marble and chlorhydric acid. The gas was dried, and collected under an oil gasometer with a capacity of 1 cubic metre. Under a pressure ranging from 4 to 6 atmospheres, the carbonic acid readily liquefies; the resulting liquid is conducted by itself in a copper tube, 4 metres long and 4 centimetres in diameter.

"Two pumps, coupled like the first, draw the carbonic acid, now from the gasometer, now from the tube filled with the liquefied gas. The access to the pumps is governed by a three-way cock; a screw-valve intercepts at will the entry of the liquid carbonic acid into the long tube; it is placed between the carbonic acid condenser and this long tube. When this regulating valve is closed, and the two pumps exhaust the vapor of the liquid carbonic acid contained in the long tube, there results the greatest possible reduction of temperature; the carbonic acid is solidified, and falls to about — 140°. The subtraction of heat is maintained, by the working of the pumps, at the rate of 100 strokes per minute, and 3 litres per stroke. The sulphurous acid tube and the carbonic acid tube are both wrapped with sawdust and rags, to diminish the influence of radiation.

"In the interior of the carbonic acid tube passes a fourth tube, designed for the compression of oxygen; it is 5 metres long, with 14 millimetres exterior diameter, and 4 millimetres interior diameter. This long tube is, consequently, imbedded in the solid carbonic acid,

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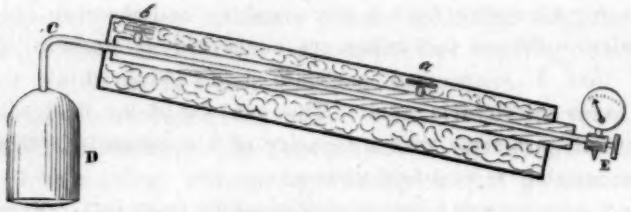
and its whole surface is exposed to the lowest temperature that can be obtained. These two long tubes are joined, by their bases, to the carbonic acid tube, so that the small tube projects about 1 metre from the other. I bend this portion towards the ground, giving the two tubes a slightly inclined position, but deviating little from horizontal, as represented in the subjoined cut. The small central tube is bent at *c*, and screwed to the neck of a strong forged iron retort, with walls 35 millimetres thick. The height is 28 centimetres, and the diameter 17 centimetres.

"This retort holds 700 grammes of chlorate of potash and 256 grammes of chloride of potassium, mixed together, melted, then bruised in a mortar, and introduced into the retort perfectly dry. I heat the retort when the two circulations of sulphurous acid and car-

Fig. 2



a, entrance of the liquefied carbonic acid.
b, exit of the vapors withdrawn by the suction pump.
The same retort and tubes are shown in the large cut at *L*, *M*, *H*.

bonic acid have reduced the temperature sufficiently. The decomposition of the chlorate of potash goes on gradually at first, and rapidly towards the end of the operation. A manometer, at the end of the long tube, enables me to observe constantly the pressure and the progress of the reaction. It is graduated to 800 atmospheres, and was made expressly by Bourdon, of Paris, this summer.

"When the reaction is over, the pressure exceeds 500 atmospheres, but it soon falls a little, and stops at 320 atmospheres. If, at this moment, the terminal screw-valve, *E* (or *P*, Fig. 2,) is opened, a liquid jet escapes with extreme violence. Closing the valve, and reopening it some minutes later, a second jet, but less copious, is seen. Coals slightly kindled, placed in this jet, burn with extraordinary violence. I have not yet been able to collect this liquid, because of its great projectile force, but I am trying to contrive a receiver, previously cooled, which will perhaps enable me, by means of cloths, to retain a little of it.

Yesterday (Monday) I repeated the experiment before a large portion of the members of our Physical Society, and we had three successive well-marked jets. I cannot yet determine the minimum pressure required, but it is evident that I have had too great a pressure, owing to an excess of gas accumulated in the retort, and which could not condense in the narrow space afforded by the inner tube.

"I expect to use a similar arrangement for attempting the condensation of hydrogen and nitrogen, and I rely on the possibility of maintaining the low temperatures very easily, thanks to the four great pumps at my disposal, moved by a steam engine.

"I believe it is in this direction that we should work in order to effect obstinate condensations, for the tensions of saturated vapors are a direct function of the temperature. I am having a sketch made of the apparatus that I used, and I shall make it a pleasure and a duty to send it to you this week. I have learned with lively interest that M. Cailletet has arrived at the same result as I, and almost at the same moment. I know nothing of his process, but I think that we shall not delay to exchange our ideas, by correspondence, upon these interesting problems.

"I beg you to excuse the brevity of this description. I will try to complete it soon, adding some figures and equations which give these results a more scientific character."

Description of M. Cailletet's Apparatus.[1]

The apparatus which I use is composed of a hollow steel cylinder, with walls thick enough to resist the pressure of many hundred atmospheres. The upper part of the apparatus has a screw groove, for attaching, by means of a bronze nut, the glass reservoir which holds the gas to be liquefied. This reservoir is formed of a thick tube of small diameter, connected with a larger tube, which plunges into the mercury with which the cylinder has been filled.

The large tube is then submitted, both internally and externally, to equal pressures, so that it may be of considerable size, notwithstanding the high pressures which it must support. The tube of

[1] From *Comptes Rendus*, Nov. 5th, 1877.

small diameter, which surmounts it, is exposed to the internal pressures, which produce liquefaction, while its outer walls only sustain the atmospheric pressure. The tube passes vertically through a metal shoulder-piece, so that all the phases of liquefaction can be followed by the naked eye. For greater security, it is well to surround this part of the apparatus with a larger cylinder filled with water.

The gas is compressed by a hydraulic pump, with the intervention of a layer of mercury. The apparatus is so simple, and so easy to operate without danger, that I hope it may be commonly employed in lectures and in laboratories, for repeating experiments of this kind.

LIQUEFACTION OF NITROGEN, HYDROGEN AND AIR.

Note by M. L. Cailletet.[1]

I have continued my experiments upon the liquefaction of gases, and I am happy to inform the Academy that I have succeeded in liquefying nitrogen and atmospheric air. Hydrogen itself gives evidence of liquefaction, as I will presently show. I submit some details of my experiments:

Nitrogen.—Nitrogen, pure and dry, compressed by about 200 atmospheres at a temperature of + 13°, then suddenly set free, is condensed in the neatest manner. There is first formed a material like a pulverized liquid, in drops of an appreciable volume; then this liquid gradually disappears from the walls towards the centre of the tube, forming a sort of vertical column in the very axis of the tube. The total duration of the phenomenon is about three seconds.

These appearances leave no doubt as to the true character of the phenomenon. I first made the experiment at home, at a temperature of — 29°, and I repeated it yesterday, Dec. 30th, a large number of times, in the laboratory of the Normal School, in the presence of many savants and members of the Academy, among whom I am happy to name, with his permission, the honored M. Boussingault.

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[1] *Comptes Rendus*, Dec. 31st, 1877.

Hydrogen.—Hydrogen has always been regarded as the most incoercible gas, because of its small density and the nearly complete agreement of its mechanical properties with those of perfect gases. It was, therefore, only with an extreme distrust of the result, that I decided to submit it to the same ordeals as determined the liquefaction of all the other gases.

In my first attempts I noticed nothing peculiar; but as often happens in the experimental sciences, the habit of observing phenomena ends in causing their signs to be recognized, in conditions under which they at first passed unnoticed. This was the case with hydrogen. In repeating the experiment, this very day, before MM. Berthelot, H. Sainte-Claire Deville, and Mascart, who authorize me to invoke their testimony, I observed indications of the liquefaction of hydrogen, under conditions of evidence which did not appear doubtful to any of the learned witnesses. The experiment was repeated many times. In operating with pure hydrogen, under a pressure of about 280 atmospheres, then suddenly set free, we saw the formation of an exceedingly fine and subtle mist, suspended in the whole length of the gas, and which suddenly disappeared. The production of this mist, notwithstanding its extreme subtlety, appeared incontestable to all the savants who saw the experiment to-day, and who took care to have it often repeated, in such ways as to leave no doubt of its reality.

Air.—Having liquefied nitrogen and oxygen, the liquefaction of air followed as a matter of course; but I thought it would be interesting to make a direct experiment, which, as might have been expected, succeeded perfectly. The air was first dried, and deprived of carbonic acid. Complete confirmation has thus been given to the accuracy of the views expressed by the founder of modern chemistry, Lavoisier, upon the possibility of reducing air to a state of liquidity, thereby producing materials endowed with new and unknown properties, views recalled so pertinently, at the last meeting, by our illustrious perpetual Secretary.

I beg, in conclusion, to express my deep thankfulness to M. Berthelot, and to my dear master, M. H. Sainte-Claire Deville, for all the encouragement that they have kindly given me, as well as for the generous hospitality which has always been shown me in the laboratory of the Normal School.

Liquefaction of NO_2.—M. Cailletet has succeeded in destroying the distinction between coercible and non-coercible gases. He has liquefied nitric acid gas, under a pressure of 104 atmospheres, by keeping the temperature at $-11°$. At $+8°$ the gaseous form is retained under a pressure of 270 atmospheres. Pure formene (CH_4), under a pressure of 180 atmospheres, at 7°, produces a mist, when the pressure is suddenly relieved, like that which arises when there is a sudden diminution of pressure upon liquid carbonic acid. This phenomenon leads him to hope for success in liquefying formene. Berthelot considers this discovery remarkably important, because it advances chemical physics beyond the limit which was reached by Faraday fifty years ago. Hitherto, none of the gases which followed closely Mariotte's law, have been liquefied, notwithstanding repeated attempts by most skilful experimenters. He has himself pushed the compression of some of those gases to about 800 atmospheres, but without success. Within a few years, Andrews has shown the reason for this failure, by showing that every vapor has a *critical point* of temperature, above which it cannot be reduced to the liquid form by any pressure, be it ever so great. Cailletet's experiments show that this critical point, for nitric acid gas, is between $+8°$ and $-11°$. Berthelot thinks it probable that most of the gases which have not yet been liquefied, such as oxygen and carbonic oxide, will succumb to the new processes which Cailletet has so happily inaugurated.—*Comptes Rendus.* C.

Free Acids in the Gastric Juice.—M. Charles Richet finds in the gastric juice only mineral acids or their analogues. When mixed with food, organic acids, analogous to lactic acid, are always found, but the mineral acid predominates until putrefaction begins. The ferment, which acidifies the alimentary materials, seems to be partly retained with the solid portions, and partly removed with the dissolved portions.—*Acad. des Sci.; Les Mondes.* C.

A New Anæsthetic.—Ch. Morel, having found that carbon tetrachloride is less liable to change than chloroform, experimented with it in the laboratory of Paul Bert; when pure it was a perfect anæsthetic, more energetic than chloroform, with an action perfectly regular. He regards it as superior to any other known anæsthetic. He describes his mode of preparation, which is a modification of that of MM. Müller and Crumps, giving better results.—*C. R.* C.

Jute Tissues.—By using jute with other textile fibres, and by employing, at the time of printing, a special distribution of colors, properly shaded, M. Jacobs obtains light-effects, which are very novel and of great brilliancy. On smooth fabrics he produces imitations of velvet in striking relief. The tissues are specially designed for decoration and furnishing, and for these purposes they offer great advantages.—*Soc. d'Enc. pour l'Ind. Nat.* C.

Determination of Longitude.—M. Faye lately addressed the French Academy, in commendation of Lœwy's method for facilitating the calculation of lunar occultations of stars. They furnish one of the best methods for finding terrestrial longitudes, but the work has hitherto been so tedious that few navigators have undertaken it. Lœwy has also prepared new tables, by which one can find the latitude of a place in two minutes, from a single observation of the polar star. C.

Specific Heat under Constant Pressure and Constant Volume.—H. Kayser has investigated the ratio between the specific heats of air under constant pressure and under constant volume, by means of experiments upon the velocity of sound in tubes. His final result is: $K = 1{\cdot}4106$. The previous estimates which he quotes are: Masson, 1·419; Weissbach, 1·4025; Cazin, 1·41; Röntgen, 1·405. [The theoretical value, based on synchronous vibrations, is 1·4232.]—*Pogg. Ann.* C.

New Carbon Battery.—M. Jablochkoff melts nitrate of potash or nitrate of soda, in which he plunges ordinary coke carbon as the active plate, and platinum as the inactive plate. Iron, or any other metal which, in presence of the carbon, is not attacked by the melted salt, may be substituted for the platinum. By adding different metallic salts, the electromotive force of the battery may be varied between 2 and 3 units; it is, therefore, superior to that of the Bunsen and Grenet batteries. The galvano-plastic deposits of the metals may be received at the inactive electrode. During the action of the battery there is a great liberation of carbonic acid and other gases. M. Jablochkoff describes an arrangement for collecting them, so that the combustion of the carbon may give simultaneously an electric current, a metallic deposit, and a motive force.—*Comptes Rendus.* C

Pliocene Man.—At the meeting of the American Philosophical Society, Jan. 18th, Prof. Cope announced the receipt of a collection of fossils from a Pliocene lake-bed in Oregon. In the deposits, in undistinguishable relation with known pliocene fossils, were found numerous flakes, with arrow and spear heads, of obsidian, many of them much tarnished by long erosion. All were lying mingled together on the surface of a bed of clay, which was covered by a deposit of "volcanic sand and ashes" of from fifteen to twenty feet in depth. This had been drifted away by the wind in some localities, thus exposing the remains. C.

Specific Heat of Vapors.—Eilhard Wiedemann has supplemented Regnault's and Winkelmann's investigations, of the specific heats of vapors and their changes with temperature, by some experiments of his own. The comparative results between corresponding temperature-limits, are:

	Regnault.	Wiedemann.
Chloroform,	·1567	·1573
Bromide of Ethyl,	·1896	·1841
Benzine,	·3754	·3946
Acetone,	·4125	·3946
Acetic Ether,	·4008	·4190
Ether,	·4797	·4943

The differences range between one-third per cent. and five per cent.—*Pogg. Ann.* C.

The Tay Bridge.—The longest railroad bridge in the world, built by the North British railway over the river Tay, at Dundee, was opened to traffic on the 25th of September, 1877. The river at this point is over 3 kilometres wide, and is navigated by ships, so that the permission for the bridge was accompanied by the requirement that it should be high enough to allow the passage of vessels. This required that the middle span should be 26·84 metres above high-water level. The whole length of the bridge is 3173 metres. The foundations of the piers were laid in iron caissons, with compressed air. The piers themselves are partly stone and partly iron. The bridge-beams, some of which weighed 190 tons, were lifted into place by hydraulic pressure. The work was repeatedly interrupted and damaged by severe storms, which occasioned the loss of many lives. Two Gramme machines were employed for night-work, with two Serrin lamps of 1000 candle-power.—*Dingler's Jour.* C.

Aroma of Butter.—A Silesian farmer suspends in his empty churn a calico bag, filled with fragrant herbs, keeping the churn carefully closed. At churning-time he substitutes four smaller bags, attaching one to each of the beaters of the churn. He thus communicates to the butter an aroma as delicate as if the cows had pastured in meadows most highly favored by nature.—*Science pour tous.* C.

New Single Liquid Battery.—M. T. Jourdan has sent to the French Academy a description of a new electric battery. The plates are zinc and plumbago; the liquid is a solution in water of the mixture, known to druggists as *sel de verre* or *fiel de verre* (unvitrified salt). He claims that it is more powerful than a Bunsen battery of the same dimensions, and that the constancy of the current is remarkable. C.

Wolff's Piano Improvement.—M. Wolff adds a third pedal, working a simple mechanism which allows the strings to prolong their notes, or subjects them at once to the action of the damper, at the will of the player. The control is increased by a small register, like those of an organ, representing an octave of which the keys command the mechanism of all the notes, and which is placed within reach of the left hand.—*Soc. d'Enc. pour l'Ind. Nat.* C.

RUHMKORFF.

We regret to record the sudden death, on December 20th, at Paris, of Henry Daniel Ruhmkorff, whose name is so closely connected with the history of magneto-electricity. He was born in Hanover, Germany, in 1803, and but little is known of his early life. In 1819 he wandered to Paris, and obtained a position as porter in the laboratory of Prof. Charles Chevalier, at that time one of the leading French physicists. Here he displayed a remarkable fondness for electrical apparatus, as well as ingenuity in its arrangement, and was enabled shortly after to start a modest manufactory of physical apparatus. Through the efforts of Chevalier, and the excellence of the work performed, the business was rapidly extended. In 1844, Ruhmkorff brought out his first invention, a convenient thermo-electric battery.

Soon after he turned his attention to magneto-electricity, especially the production of the induced currents, discovered by Faraday, in 1832. A long series of experiments resulted in the appearance, in 1851, of the famous "Ruhmkorff coil," with its later modifications, the most important piece of apparatus in this branch of physics. With this powerful adjunct the electrician was enabled to obtain sparks 18 inches in length, pierce thick plates of glass, and carry out a vast variety of experiments. The invention was rewarded by a decoration and medal at the Exhibition of 1855, while in 1858 it received the first prize of 50,000 francs at the French Exhibition of Electrical Apparatus. Since then the manufacture of the coils and of electrical machines in general, has assumed enormous dimensions, and the leading physicists of Europe are well acquainted with the dingy little bureau in the Rue Champollion, near the University. Personally, M. Ruhmkorff was of a quiet, dignified appearance, and despite the disadvantages of his early life, he enjoyed the friendship of the leading Parisian *savants*, and was an honored member of the French Physical Society. M. Jamin delivered an address over the grave, in which he stated that Ruhmkorff died almost a poor man, because he had spent all his earnings on behalf of science and in works of benevolence.—*Nature.*

Book Notice.

A Guide to the Determination of Rocks.—By Dr. Ed. Jannettaz. Translated from the French by Geo. W. Plympton, C. E., A. M. D. Van Nostrand, 1877.

This is a practical work intended as an introduction to the study of Lithology, and to furnish data for determining rocks by physical characteristics and simple blow-pipe and chemical tests, and as such it is of no little value; but the task undertaken is too great for the brevity of this work. The minerals composing, and commonly contained in, the rocks are dismissed in fifteen pages; the descriptions are good, but, necessarily, too brief; the description of the rocks themselves covers but eighty pages, the rest of the work being devoted to tables for the determination of the rocks. In this small space, however, a great deal of information is given. It is to be

regretted that the book was not subjected to more careful supervision before going to press, and some, at least, of the palpable errors, such as the following, corrected:

P. 26, Micas. The laminæ are *flexible* and elastic.
P. 27. Muscovite Micas, very *rich* in *Magnesia*.
P. 29, Talc and Steatite. Silica about 62 per cent., Magnesia 32 to 33 per cent., Water 48 per cent.
* * The *base* is cleavable.
P. 58. The Basalts of the County of Antrim, Ireland, contain Sulphate of Copper in solution, and owe this property, without doubt, to metallic iron intimately mixed.
P. 85. Sulphates of Iron and Alumina used as fertilizers.

A very objectionable feature of the work is the insertion of a great number of advertisements, occupying one-fifth of the book, and throwing the index in a position not easy of reference. If purchasers of books must pay for so large an amount of matter not pertinent to the subject, we think all would prefer it in a separate volume. R.

Franklin Institute.

HALL OF THE INSTITUTE, Jan. 16th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 128 members and 6 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 10 persons were elected members of the Institute, and the following donations were made to the Library:

Descriptive and illustrated catalogue of the Pratt and Whitney Co., Hartford, Conn. From the A. O. Granger.

Specifications and Drawings of Patents, U. S. Patent Office, July, 1877. From the Patent Office.

Indian Meteorological Memoirs. Calcutta, 1876.
Report on the Meteorology of India in 1875.
Report of the Vizagapatam and Backergunge Cyclones of Oct., 1876. By J. Elliott. Calcutta, 1877.

Report on the Administration of the Meteorological Department of the Government of India in 1875–76.
From the Meteorological Department of the Government of India.

United States Geological Exploration of the Fortieth Parallel. C. King, Geologist in charge. Vol. 2, Descriptive Geology. Washington, 1877.
Reports of the Chief of Engineers, U. S. A., for 1867, 1869, 1871 to 1873, inclusive.
From the Chief of Engineers, through E. Hiltebrand.

Papers read before the Pi Eta Scientific Society, 1877. From the Society, Troy, N.Y.

Catalogue of the Trustees, Officers and Students of the University of Pennsylvania, 1877–78. 1st Ed. From L. M. Haupt.

On the Dynamical Law of Horse-power of Steam Boilers, by J. W. Nystrom. Philadelphia, 1875. From the Author.

59th Annual Report of the Trustees of the New York State Library for 1876. From the Trustees.

The Metric System, by H. Hamilton. Harrisburg, 1877. From the Author.

The President presented and read the following Annual

REPORT OF THE BOARD OF MANAGERS TO THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA, FOR THE PROMOTION OF ARTS, FOR THE YEAR 1877.

Your Board of Managers beg respectfully to submit the following Report:

Members.—During the year, 135 persons were elected members of the Institute, and 37 resigned. Of the deaths of our members we have no means of reporting with accuracy; of one, however, we desire to make a record, from the fact of his having joined the Institute at its first meeting in 1824, and continued a contributing member up to the time of his decease in October, 1877. We refer to Mr. George S. Lang, whose name is the fiftieth attached to our constitution; but two members are now living who signed the constitution before Mr. Lang, viz.: Mr. Frederick Fraley, our Treasurer, and Mr. Geo. Gardom. Mr. Lang, at the time he joined the Franklin Institute, was an engraver of considerable reputation; he after-

wards went into the dry goods business on Eighth Street, from which he retired about ten years ago. Recently he spent two years in finishing a large engraving of the "Landing of Columbus," which he had commenced fifty years before, and an impression from the plate was exhibited in the Art Gallery of the Centennial Exposition.

Treasurer's Report.—The Treasurer's Report, which will be read to the Institute this evening, exhibits the following summary:

Receipts.

Balance on hand Jan. 1st, 1877, . . .	$ 992 01
Sale of investment securities, . . .	5,400 00
Receipts from all other sources, . . .	11,986 19
Total, ...	$18,378 20

Payments.

5 per cent. building loan and interest, . .	$ 3,273 75
All other payments, ...	13,294 97
Balance on hand Dec. 31st, 1877, . .	1,809 48
Total, ...	$18,378 20

This statement shows a diminution in the permanent capital of the Institute of $1308.78.

Premiums and Medals.—The following premiums and medals were awarded during the year:

Elliott Cresson gold medal to P. H. Dudley, of Cleveland, Ohio, for his Dynograph, for measuring and graphically recording resistances of railway trains.

Scott Legacy premium and medal to George B. Grant, of Boston, for his calculating machine.

Journal of the Institute.—During the earlier portion of the past year, the JOURNAL was, as heretofore, under the control of an editor, assisted by the committee on publication, but since the 1st of April it has been more immediately under the direction of the committee on publication, aided by the Secretary of the Institute. Its cost of publication has been considerably less than for several preceding years, and its subscription list well maintained.

Drawing School.—The attendance at the night drawing school has not been quite so large as during the previous year, owing, it is

believed, to the continued depressed condition of business affecting in a special degree those who would seek that kind of instruction.

Lectures.—The lectures given during the earlier part of the year, from Jan. 2d, to March 20th, which were of the illustrated series, were: by Mr. Henry Whitall, on Astronomy; Mr. A. E. Outerbridge, on Metallurgy and Assaying of Gold and Silver; Prof. Elihu Thomson, on Electricity; Prof. P. E. Chase, on Inventions of the Century, Ornamental Iron Work, and on Ceramics. And those which were of the elementary series were by Prof. Wm. D. Marks, on the First Principles of Dynamics; Prof. Elihu Thomson, on Elementary Chemistry.

Last year the experiment was made, of having two classes of lectures, one of a highly illustrated character, giving popular instruction in the more advanced grades of science, and especially illustrating and fixing in the minds of hearers, the facts treated of in scientific journals; the other class, more elementary and strictly educational in character.

The success attending that effort was sufficient to warrant its repetition this winter; and it is believed that, with the increased facilities now furnished to lecturers, still more satisfactory courses will be given.

The Board of Managers have authorized the purchase of a Dynamo-Electric Machine, which will add greatly to the scope and brilliancy of the illustrated series.

In place of lectures on Mechanics, in the elementary series, there has been substituted a course on Physics, giving a wider scope, and embracing those elementary laws and properties of matter of more general application.

With the view of increasing its usefulness, the admission of non-members to the elementary course is fixed at the nominal price of $1.00 for the sixteen lectures.

Under this arrangement the following lectures were given during November and December:

In the Illustrated Series, by Prof. Houston, on the "Contrasts and Resemblances of Sound and Light."

And in the Elementary Series, by Prof. E. H. Bartley, on Chemistry.

Prof. Houston also gave, gratuitously, an entertaining familiar lecture to the "young folks" during Christmas week.

Phonography.—Two courses of lectures on this subject were given during the year by Mr. D. S. Holman.

The Board feel much satisfaction in the assurance they have of the solid usefulness of the various lectures which have been given during the year, and of the interest manifested in them by the large and increased attendance by the members of the Institute and others.

As one of the important outgrowths of the lectures on Phonography, a section of the Institute has been established under the title of the "Phonetic Shorthand Section of the Institute."

Monthly Meetings of the Institute.—The attendance at the monthly meetings, of members and strangers, has been quite as large during the past year as in any previous one—and many interesting communications, inventions and novelties have been presented and discussed on those occasions.

Library.—The Board were unable to appropriate as large a sum for the use of the Committee on the Library as was expended last year. The Committee on the Library will report what has been done towards its improvement during the year.

By order of the Board,

R. E. Rogers, *President.*

Report of the Committee on Library.

The Committee respectfully report that they have held monthly meetings, which have been fairly attended by the members.

The Committee requested the appropriation of $2500 for the library during the year, but only the sum of $1500 was found available for this purpose, and this was appropriated, and the amount was expended as follows:

For the purchase of new books,	$605 94
For binding books,	656 40
For binding British Patents,	54 25
For incidental expenses, freight, etc.,	165 31
	$1481 90

Leaving an unexpended balance of $18 10.

In addition to the above amount expended in cash, there were received books and exchanges, for which the Committee on Publication was credited, to the amount of	435 00
Making total amount for the improvement of the Library,	$1916 90

The following additions were made to the Library during the year:

Unbound books, donations,	2835
Bound books, donations,	168
Unbound books purchased,	193
Bound books purchased,	139
Exchanges, bound,	250
Books other than exchanges, bound,	388
Books re-bound,	64
Books repaired,	7
Maps donated,	9
Maps purchased,	19
Plans of buildings purchased,	25
The number of bound vols. in Library, Dec. 31st, 1876,	11,966
The number of bound vols. added in 1877,	945
The number of bound vols., Dec. 31st, 1877,	12,911
The number of unbound vols in Library, Dec. 31st, 1877, is estimated at	6,000
Total,	18,911

During the year 1877, books were taken out by 292 members, an increase of 68 over 1876.

The total number of books taken out by members during 1877, was 2112, an increase of 925 over the year 1876, which indicates an increased use of the library, by members, of about 75 per cent.

This number of books taken out may seem small, unless it be remembered that our library is largely composed of works of reference. The very marked increase in the circulation of books is an index of the increased use of the library by members, for consultation.

The subject of completing our set of French Patents, has received the attention of the Committee, and some of the wanting volumes have been purchased, and all those in the library, 111 vols., well bound; and it is expected that the remainder will be purchased and bound out of the appropriation for 1878.

While the funds at the disposal of the Committee are chiefly devoted to the acquisition of the latest and best books upon subjects within the scope of the Institute, we have been mindful of the advantage of completing our sets of several publications containing the original history of science by discoverers and inventors in their own language. As an example, we have just succeeded in com-

pleting our copy of the memoirs of the old French Academy, from 1666 to 1790, by the purchase of two odd volumes of the memoirs, and ten vols. of the indexes.

By order of the Committee.

WM. P. TATHAM, *Chairman.*

Mr. J. B. Knight, representative of the Institute in the Pennsylvania Museum and School of Industrial Art, presented the following report:

In my Report of June 20th last,[1] the hope was expressed that the schools contemplated in the charter would be put in operation before the end of the year, and I now have the satisfaction of reporting that this has been accomplished.

During the summer a special effort was made to raise funds for the maintenance of the schools, which proving satisfactory, the building No. 312 North Broad Street was secured, and fitted up in a manner admirably suited to the wants of both pupils and teachers.

The course of study decided upon consists of instruction in drawing with instruments, covering the ground of plane and descriptive geometry, projective and perspective, and also free-hand drawing, including manipulation with pencil, charcoal and brush, from study of natural objects, casts, architectural details, and objects from the Museum collection. This will be followed by a study of color, and its application and disposition in design, together with the preparation of original designs suitable for practical application.

The class instruction will be supplemented and reinforced by lectures on kindred subjects.

While the course of instruction adopted presents no novelty, it is intended to make the training thorough, so that those availing themselves of its advantages may be well grounded in the principles underlying what is known as design.

The persons selected as instructors are: Mr. Charles M. Burns, in the artistic division of the course, and Mr. Philip Pistor, in the scientific branches; and, as lecturers, Dr. J. T. Rothrock, on Botany as applied to decorative art, and Mr. Geo. Herzog, on Historic Ornament.

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[1] See Vol. civ, page 6, July, 1877.

It having been decided that the instruction shall be free to citizens of the commonwealth, of either sex, it became necessary to adopt a standard of examination that requires a knowledge of the rudiments of drawing on the part of the applicant, and to adopt rules which should demand earnest work of the students, and prevent the classes being filled with incompetent or careless students. This was done with the advice and aid of the instructors, and, out of about 200 applicants, 100 were selected as proficient; and the schools were opened on December 17th, with this number of students, it being the maximum that could be accommodated.

Special classes in art needlework, embroidery and lace-work, have been formed, and Miss Mary Jones Atkinson, from the Royal School of Art Needlework, London, appointed instructor. Tuition in these classes is free to those who are unable to pay, but, to meet the demand for this kind of instruction among persons who were able and willing to pay, a few classes of pay pupils have been formed, and so arranged as not to interfere with the free classes, yet aiding considerably in supporting the schools. The Committee on Instruction has been aided in the organization and management of these classes, by twelve ladies, who have kindly consented to act as an Advisory Committee.

The work of organizing and managing the schools was placed in the hands of the Secretary, Mr. H. Dumont Wagner, under the direction of the Committee on Instruction; and the Trustees speak highly of the manner in which he has performed this as well as his other duties.

It is to be understood that the schools, as now arranged, are but a beginning, to be amplified and extended as circumstances will permit, and if this effort on the part of the trustees meets that support which its importance demands, it must prove of immense value to the industries of the state.

Several valuable and interesting objects have recently been added to the collections, and among those worthy of special mention are the models, in cork, of Windsor Castle and the Tower of London, by Lloyd Hoppin. These were presented by a committee of members.

The number of visitors to the Museum collection in Memorial Hall since the opening, May 10th, 1877, to Jan. 1st, 1878, was 147,113. The Trustees, wishing to give the widest effect to the educational influences of the collections, decided to open them to the public on Sun-

days, and this was done, commencing July 24th, since which time 20,280 persons have visited the Museum.

In the early part of the year the By-Laws were amended in such a manner as to place the active work of the corporation in the hands of an Executive Committee, consisting of thirteen members of the Board, together with the President, Vice-Presidents, Treasurer and Secretary.

An election was held on the 14th inst., with the following result:

President, Coleman Sellers.
Vice-Presidents, Ed. T. Stevens, Wm. Platt Pepper.
Treasurer, Clarence H. Clark.
Secretary, H. D. Wagner.
Executive Committee.—W. H. Merrick, Chapman Biddle, Samuel Wagner, Jr., F. O. Horstmann, W. W. Justice, Thomas Cochran, J. Vaughan Merrick, J. B. Knight, Adam Everly, Wayne McVeagh, T. R. Shelton, J. C. Brown, J. R. Baker.

The Report of the Board of Trustees, giving a history of the corporation, from its organization to Dec. 31st, 1877, will shortly be printed, and then may be had on application at the office, No. 312 North Broad Street.

J. B. KNIGHT.

Mr. Edward R. Andrews, of Boston, Mass., read a paper on creasoting timber, including a description of the Hayford process and apparatus for preserving wood.[1]

The Secretary presented his report, embracing Murphy's Pneumatic Fire Extinguisher, Evarts' Health Lift apparatus, and the Eureka Self-Lighting Gas Burner.

The tellers presented their report of the annual election held this day, which was accepted, and, in accordance therewith, the chair declared the following members elected:

President, R. E. Rogers, M. D.
Vice-President, Chas. S. Close.
Secretary, J. B. Knight.
Treasurer, Frederick Fraley.

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[1] See page 109.